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FUTURE

VOLUME 4

Feed your mind and learn more about the incredible world around you

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HOW IT WORKS

The Collection

Volume 4

How It Works The Collection is a compendium of the planet's most incredible facts that will feed your mind and give you answers to questions you've never even thought to ask!

Through in-depth articles, detailed illustrations and eye-catching images, we delve deep to answer some of the biggest what-ifs and uncover the planet's most incredible secrets.

Over the following pages, examine science, technology, the environment, transport, space and history. Topics range from engineering marvels, such as electric cars and the next-gen Concorde, to earthquakes and allergies. Travel to the Moon, uncover how fossil hunters are discovering new species of dinosaurs and find out if it's possible to slow the ageing process. Read on to learn more about the world around you!

FUTURE

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Volume 4

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Bookazine Editorial
Editor **Daniel Peel**
Designer **Katy Stokes**
Senior Art Editor **Andy Downes**
Head of Art & Design **Greg Whitaker**
Editorial Director **Jon White**

How It Works Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Editor-in-Chief **Gemma Lavender**

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Media packs are available on request
Commercial Director **Clare Dove**

International
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com
www.futurecontenthub.com

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Matthew Eglinton**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Managers **Keely Miller, Nola Cokely, Vivienne Calvert, Fran Twentyman**

Printed by William Gibbons, 26 Planetary Road, Willenhall, West Midlands, WV13 3XT

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Chief executive **Zillah Byng-Thorne**
Non-executive chairman **Richard Huntingford**
Chief financial officer **Rachel Addison**

Tel +44 (0)1225 442 244

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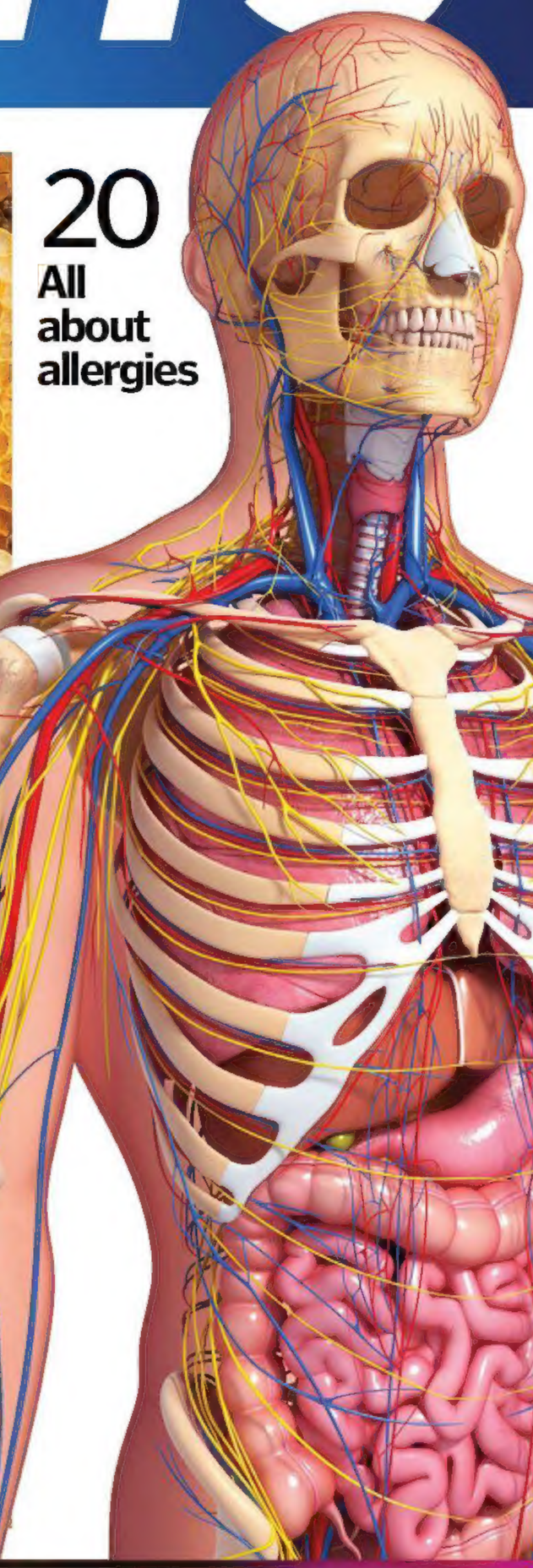

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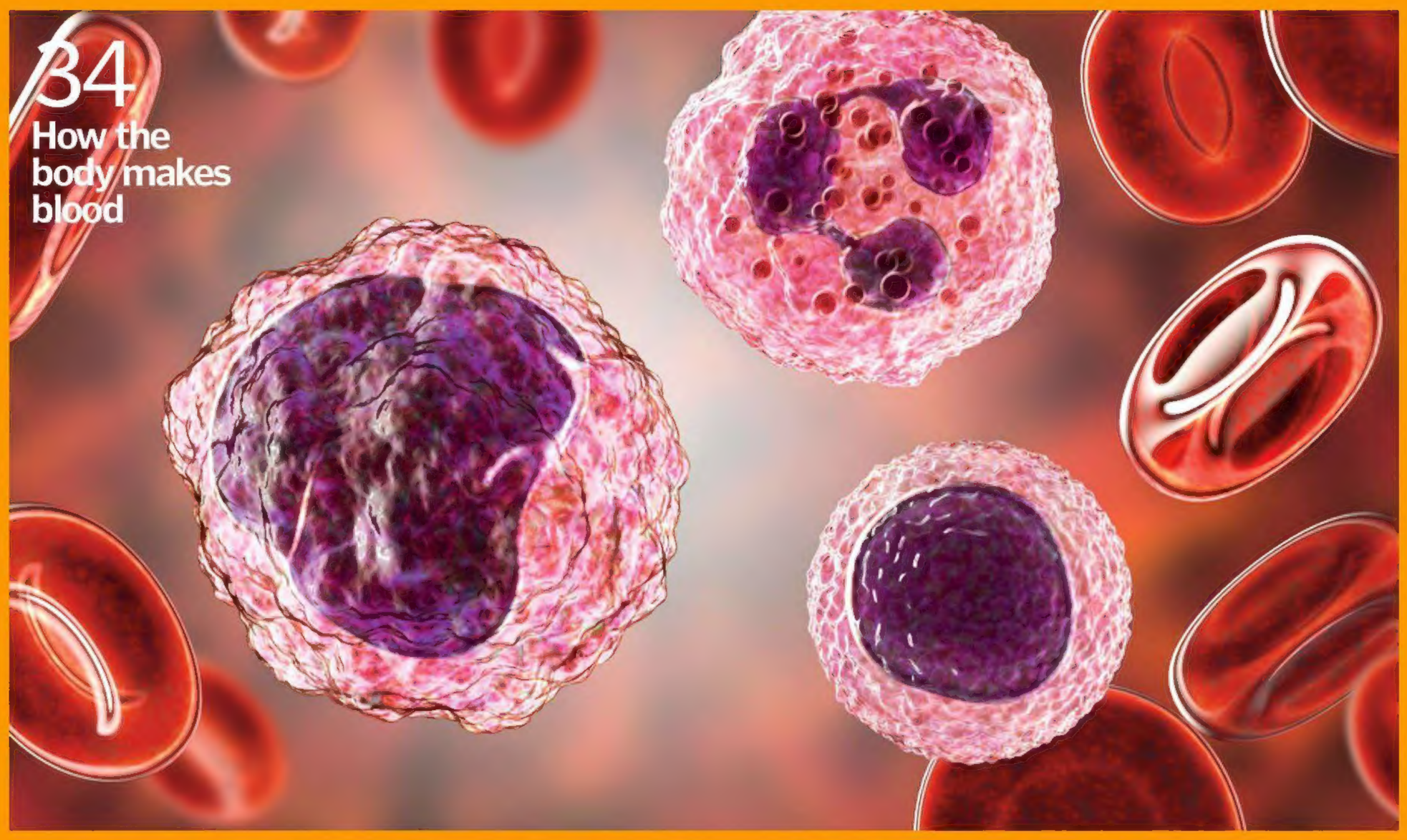

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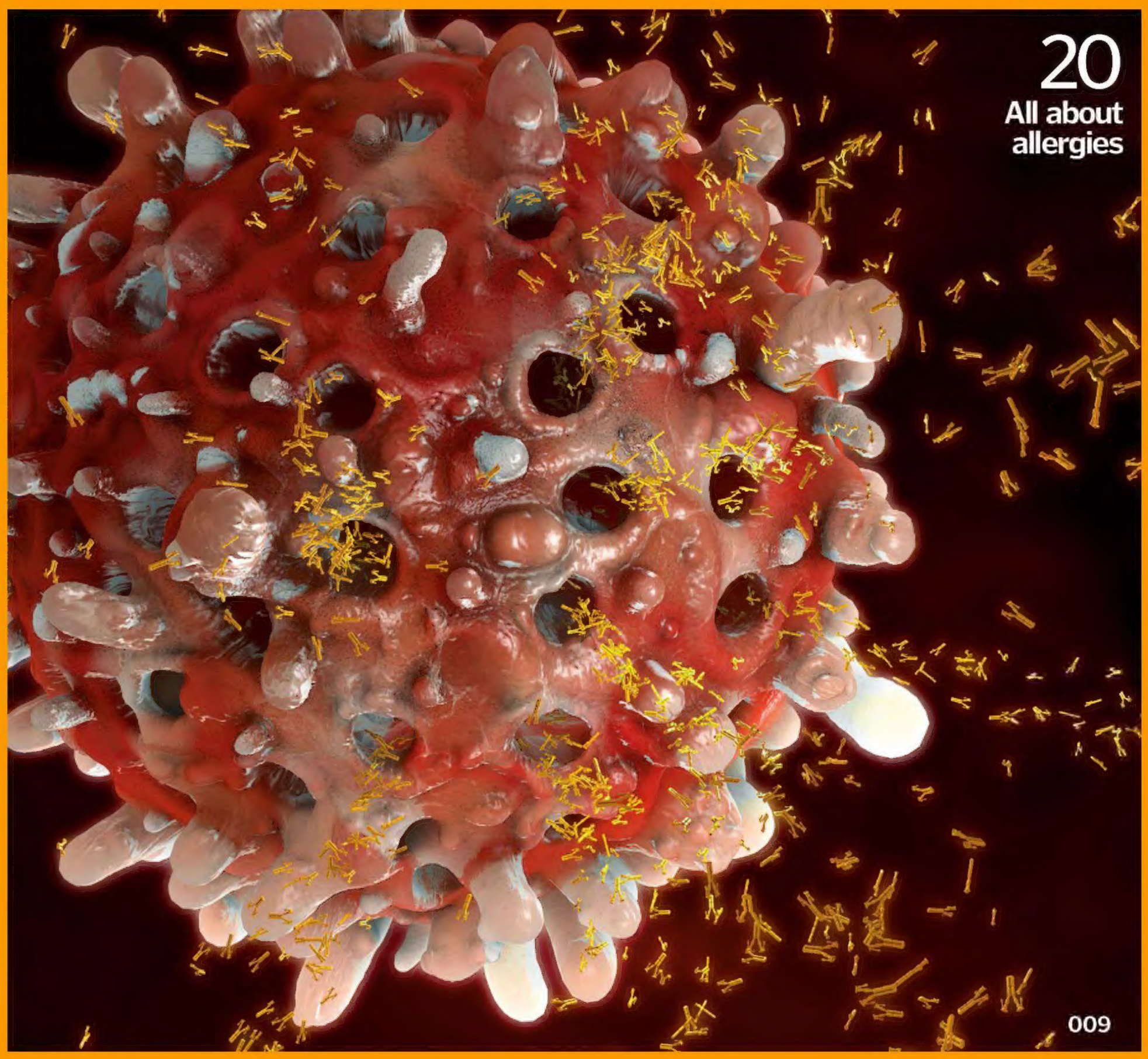

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CAN WE LIVE FOREVER?

What is ageing and why do we get older? **How It Works** looks at the science of senescence and the technologies tackling the inevitable

Words by **Scott Dutfield**

Ageing is a fact of life we can't escape no matter how hard we try, though as a species we're getting better at prolonging the process. For the first time in human history, the global average life expectancy is above 70 years old. In comparison, back in 1950 the global average was only 45 years old. We can predominantly thank the advancement of medicine for letting us live longer, but at what point do we stop growing and start ageing?

It's generally understood that once we surpass sexual maturity in our late 20s we make the transition from developing into ageing, also referred to as senescence, which means 'the process of growing old'. After sexual maturity, our bodies become less efficient at dealing with physical stress and maintaining biological systems. That seems to be because of the way our species has evolved.

It might make more sense that, like any machine, if you keep your body well-fuelled and maintained, you could live indefinitely. Generally speaking, many evolutionary biologists have concluded that we age simply because the driving force of evolution, known as natural selection, hasn't selected for fitness and function at an older age.

Of course, humans aren't alone in this. The majority of other species have evolved a similar reproductive life cycle – but not all of them. Many cold-blooded species such as lizards retain their fitness and reproductive abilities and are considered to have negligible senescence. These animals age very slowly and typically die from non-age related events such as predation, disease or natural disasters.

CELLULAR AGEING

Although we recognise ageing in humans as wrinkled skin, joint pain and grey hair, senescence occurs on a much smaller scale. More than 37 trillion cells make up the human body, and each one will have its own life cycle that contributes to your body's overall ageing.

Each of your cells has a Hayflick limit, named after the scientist Leonard Hayflick, who discovered it. This limit is how many times a cell can divide before it can't divide anymore and dies. A normal human cell has a Hayflick limit of between 40 and 60 divisions. This is because

AR ZONE!

Cell shutdown

How apoptosis systematically destroys cells

Shrinking
Once an internal signal triggers the beginning of apoptosis and self-destruction, the cell membrane begins to shrink.

Blebbing
The membrane puckers and forms bulbous structures called blebs.

Complete collapse
Organelles, such as the cell's nucleus and mitochondria, are broken down within by internal enzymes.

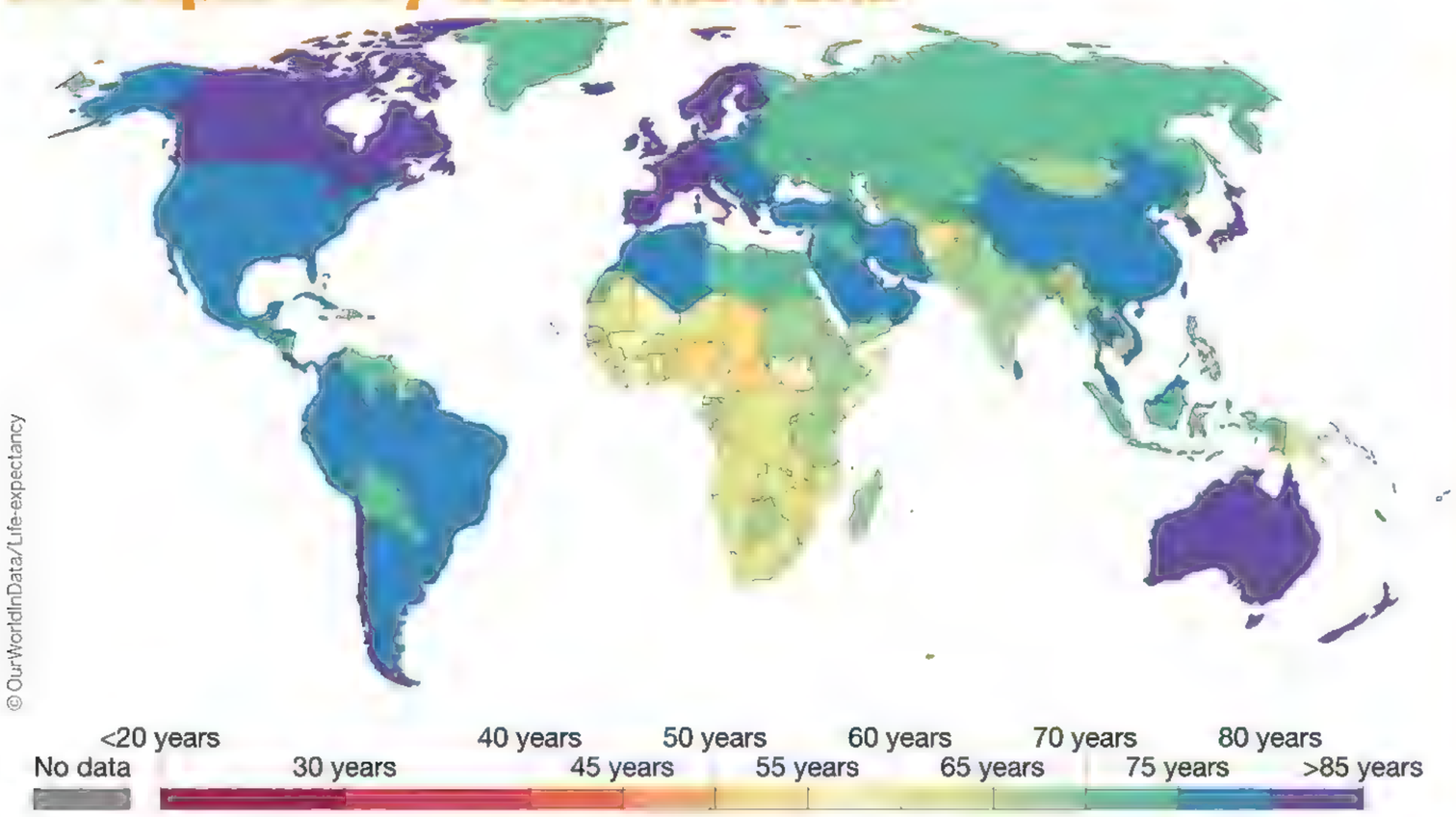
Breaking apart
The cell membrane breaks up after blebbing, forming small pockets of apoptotic bodies.

Digestion
Large immune cells called macrophages engulf the apoptotic bodies and destroy them.

An animation of three cells in programmed death. Scan the AR code to watch them being broken down

AR ZONE! SCAN HERE

Life expectancy around the world



with each division cells lose some genetic information. Long chains of DNA called chromosomes in the cells' nuclei lose non-coding sequences of DNA called telomeres from their tips. With each replication these telomeres become shorter and shorter, until the cell can no longer successfully divide.

Reaching their limitations, cells will undergo a form of self-destruction called apoptosis, from the Greek word for 'falling off', referring to leaves on a tree. This orderly process involves enzymes, called DNases, breaking down a cell's genetic information. Immune system cells called macrophages eat up the cell's remains and remove it. This is different from necrosis, however, whereby a cell will die away after it is physically damaged.

This cellular life cycle is what keeps our bodies in check; without a Hayflick limit, cells would continue to divide, growing to form masses. For example, cancer cells have no Hayflick limit, which is why they grow rapidly and form tumours that can spread around the body easily.

However, it is believed that when a cell's DNA is damaged, the process of apoptosis is halted, and the cells become 'senescent'. Stuck in a phase between being alive and dead, these are often referred to as 'zombie cells'. They can no longer perform their allocated function, and they also stop reproducing. As a result, the cells build up and become a major contributor to the process of ageing.

As these zombie cells linger over time, they cause inflammation and other age-related diseases such as cancer and cardiovascular disease. They play a particular role in the degradation of neighbouring tissue and cells, which leads to the development of degenerative disorders related to age such as dementia.


© A amy

This is the oldest person alive, Kane Tanaka, who celebrated her 118th birthday this year

Too old to age

Is it possible for a human body to reach a certain age and just stop ageing? A study conducted in 2018 found that yes, it can happen, but you have to reach 105 years old first. Research conducted at the Sapienza University of Rome in 2018 found that, when looking at 3,836 Italians who were over the age of 105 between 2009 and 2015, the risk of death plateaued.

As we age our risk of death naturally increases – for example, in your 50s the risk of dying is three-times higher than in your 30s. However, the study suggests that the probability of living between 106 and 107 years is the same as 111 and 112 years. It remains unclear as to why this might be, with the need for more study into potential contributing factors, such as genetics.


© Getty

If you reach your 100th birthday, you have a 60 per cent chance of celebrating your next one

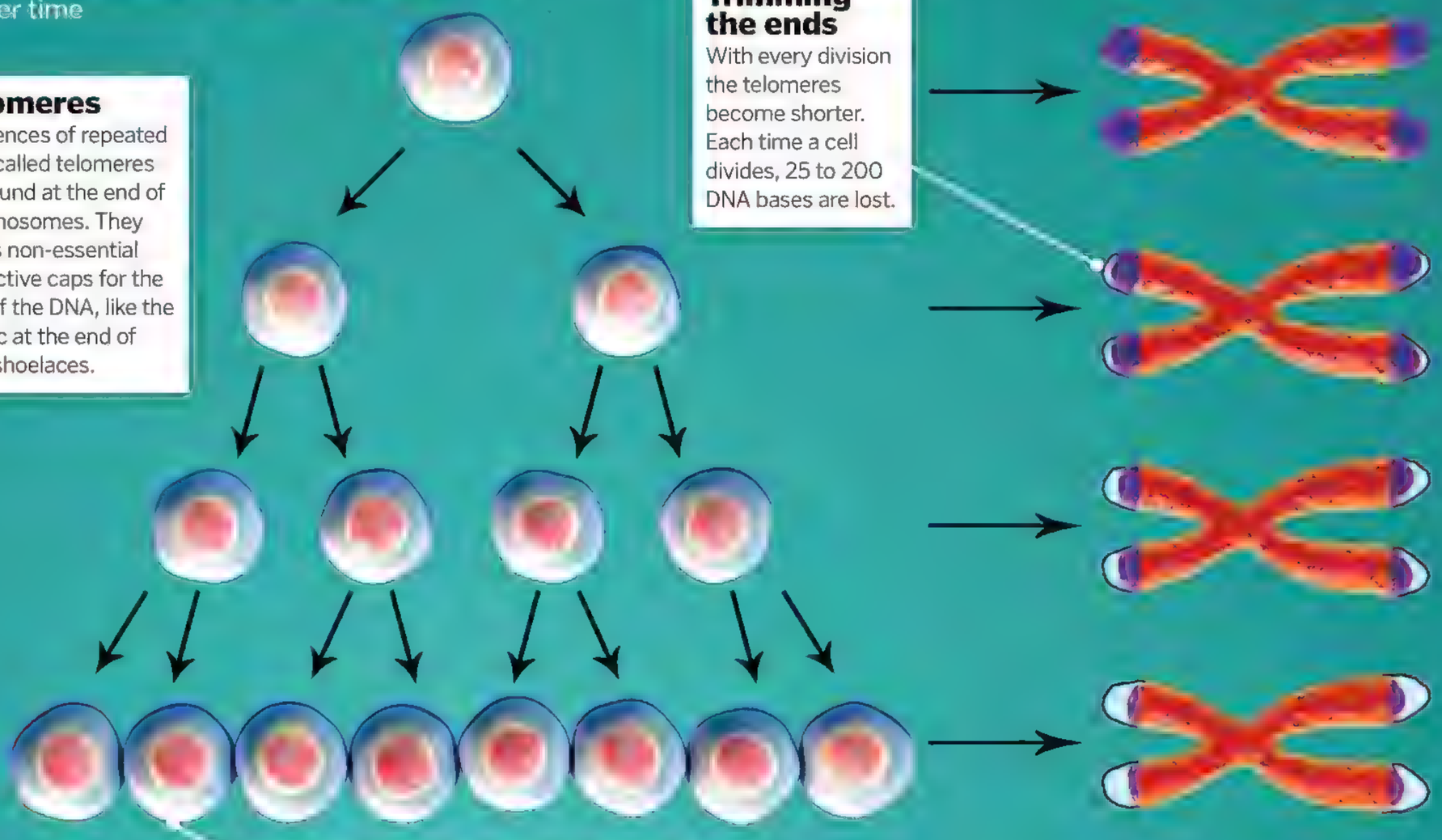
© Getty

Cutting chromosomes

Here's how telomeres shorten over time

Telomeres
Sequences of repeated DNA called telomeres are found at the end of chromosomes. They act as non-essential protective caps for the rest of the DNA, like the plastic at the end of your shoelaces.

Trimming the ends
With every division the telomeres become shorter. Each time a cell divides, 25 to 200 DNA bases are lost.



Chromosome
Each cell in our bodies contains 23 pairs of long DNA chains called chromosomes.

Cell division
Human cells can divide 40 to 60 times before reaching their Hayflick limit. However, stem cells have a few more, around 72 times.

Forming wrinkles

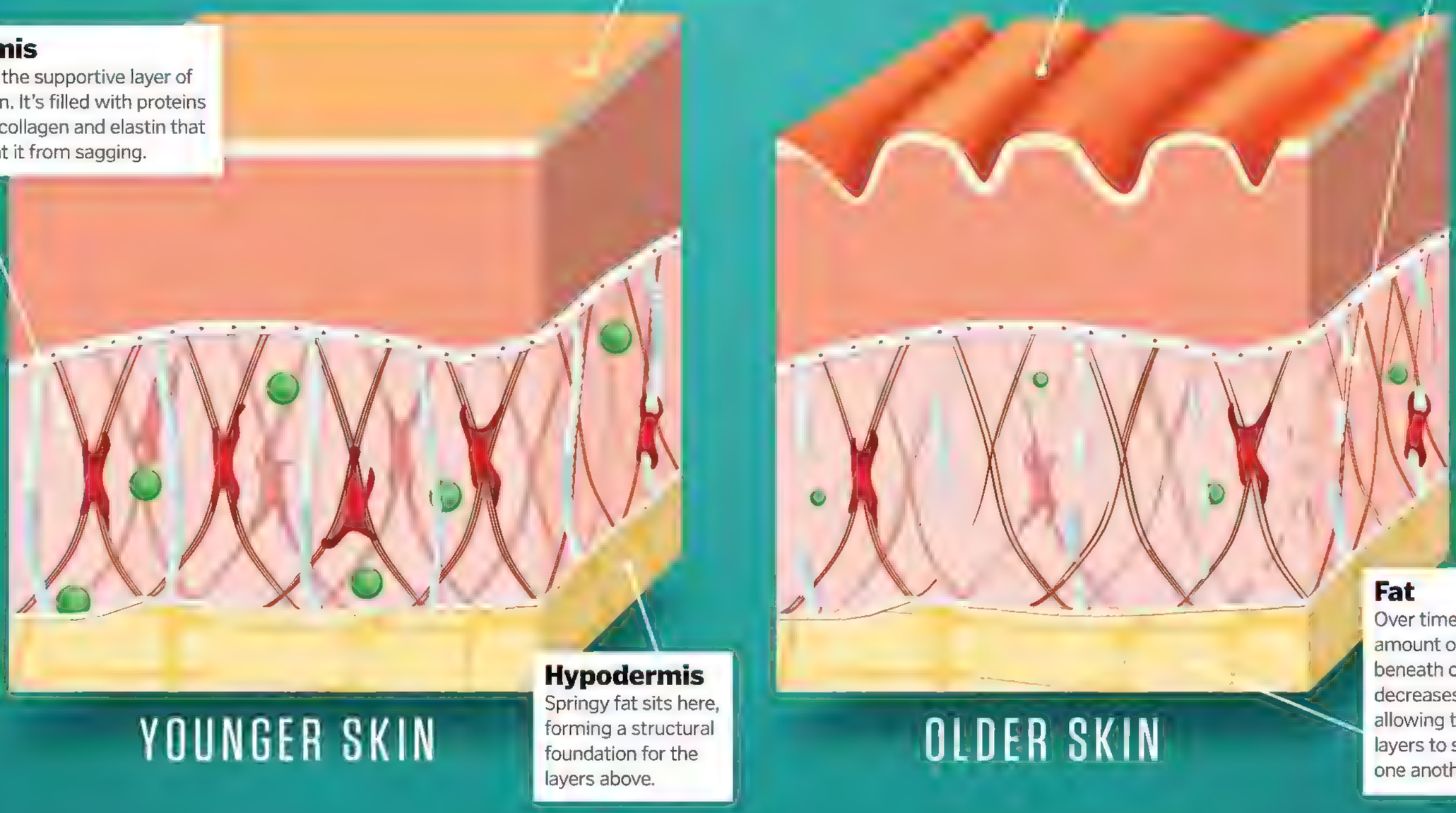
How skin folds to create laugh lines

Epidermis
Younger skin is packed with lots of moisture, keeping it smooth and plump.

Moisture
Wrinkles begin to form when a lack of moisture causes skin to fold into the dermis layer.

Collagen
Levels of collagen and elastin are diminished over time, which act like support beams for the epidermis.

Dermis
This is the supportive layer of the skin. It's filled with proteins called collagen and elastin that prevent it from sagging.



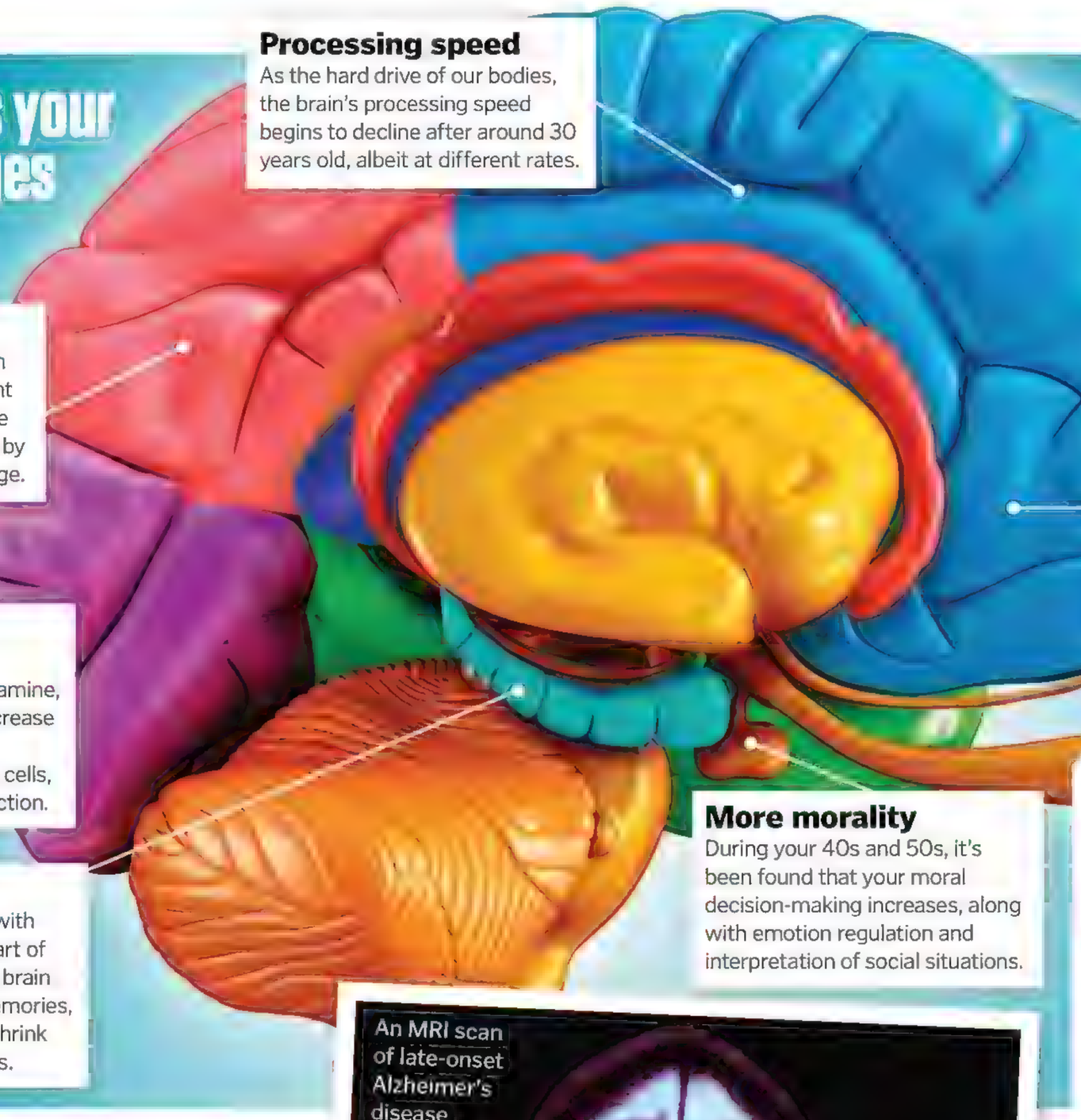
YOUNGER SKIN

OLDER SKIN

Hypodermis
Springy fat sits here, forming a structural foundation for the layers above.

Fat
Over time the amount of fat beneath our skin decreases further, allowing the above layers to sag into one another.

Seven ways your brain changes as you age



Processing speed
As the hard drive of our bodies, the brain's processing speed begins to decline after around 30 years old, albeit at different rates.

Getting thinner
The cerebral cortex begins to thin during middle age. This cortical thinning leads to reduced memory and cognitive function.

Shrinkage
At around 30 years old your brain begins to shrink, albeit at different rates and in different regions. The decrease in size ramps up a little by the time you reach 60 years of age.

Attention span
From as early as your 20s, your ability to manage multiple tasks like reading a recipe while listening to music, or filter out distractions like followong what your friends are saying in a busy restaurant, can become more difficult.

Chemical communication
Neurotransmitters such as dopamine, acetylcholine and serotonin decrease as we age. These enable the communication between nerve cells, which give us our cognitive function.

More morality
During your 40s and 50s, it's been found that your moral decision-making increases, along with emotion regulation and interpretation of social situations.

Memory
We often associate ageing with losing our memories, and part of that is because areas of the brain associated with forming memories, such as the hippocampus, shrink over time from your mid 30s.


An MRI scan of late-onset Alzheimer's disease

THE APPEARANCE OF AGEING

Greying hair is a universal symbol for ageing. It's commonly misunderstood that your hair 'turns' grey, when in fact it's just your hair follicles running out of pigment over time. This biological hair dye is called melanin, and it's also the pigment that gives your skin its colour. As we age, the production of melanin at the follicles declines, and grey hair begins to emerge, typically from your 30s. Around 50 per cent of the population will be at least partially grey by the time they are 50. But melanin decline isn't exclusive to hair follicles as we age. Our number of melanin-containing skin cells, called melanocytes, decreases by 8 to 20 per cent per decade after the age of 30.

Along with the loss of melanin, our skin also loses components that keep it firm and smooth, such as collagen and elastin. After the age of 20, a person makes around one per cent less collagen in their skin every year. This leads to the formation of wrinkles, and generally less plump skin. What do appear to continue to grow, however, are our ears and noses. Researchers at the University of Milan calculated that the total surface area of the nose of people aged 65 to 80 years old is typically 15 per cent larger than a nose on the face of an 18 to 30 year old. This is because as we age, the cartilage that has built those features goes through a process that makes it thicker but less elastic.

The process of ageing doesn't affect us all equally. Many of us go grey or lose our hair sooner than others, and wrinkles will appear at different stages of our lives. Our bodies are unique and are affected by our genetic blueprints and the impact our environment has on us, meaning that everyone ages at different rates. A study from Duke University explored this on a cellular level. Researchers monitored different markers for risks of age-related disease, metabolism and the length of telomeres of 1,000 participants. The researchers checked in on them at 26, 32 and 38 years old, and found that in general, participants' biological age correlated with how many birthdays they had celebrated. However, there were some extreme exceptions. One participant had a biological age of 28 – essentially not ageing since the trial began – while another had biologically aged to around 61. That suggests that they aged three years for every birthday on average.

5 WAYS TO KEEP YOUR MIND SHARP

1 Exercise
Studies in animals have found that regular exercise increases the number of blood vessels that feed oxygen to your brain. It's also been found that new nerve cells and the connections between them are increased, which improves your cognitive abilities.

2 Sleep
Getting seven to eight hours of sleep a night has been found to consolidate memories more efficiently. Some studies have found that bad sleep increases proteins in the brain that contribute to impaired brain function.

3 Eat well
Having a healthy diet will improve many aspects of your life, but studies have shown that those eating a Mediterranean-style diet filled with vegetables, nuts, fish and fruit are less likely to develop conditions such as Alzheimer's.

4 Stay social
Social interactions have never been more important to our mental health, but regarding ageing, safe social interactions help prevent the effects of depression and stress, which contribute to memory loss.

5 Train your brain
Completing puzzles such as jigsaws, sudoku or crossword puzzles stimulates new connections between brain cells and develops your brain's ability to problem solve and adapt to new situations.

WHO WANTS TO LIVE FOREVER?

The science that seeks to slow down the process of ageing

Uploading our minds might be possible with future technology

Upload yourself

There may come a point when attempts to prevent ageing turn from the biological to the digital. If you truly want to live forever, then uploading your brain may be a real option in the future. When, however, remains unclear. The science is called Whole Brain Emulation (WBE), and in theory it would involve uploading your consciousness into a computer, including all of your thoughts and feelings. However, the first and biggest hurdle scientists face is mapping the human brain. There are roughly 86 billion neurons in your head and each neuron can connect to 10,000 other neurons. Thus far scientists have only been able to map the 302-neuron brain of a nematode, so we're a long way off navigating the human mind. Nevertheless, many tech companies and research institutes are working to map the whole brain in the hopes of one day recreating it online.

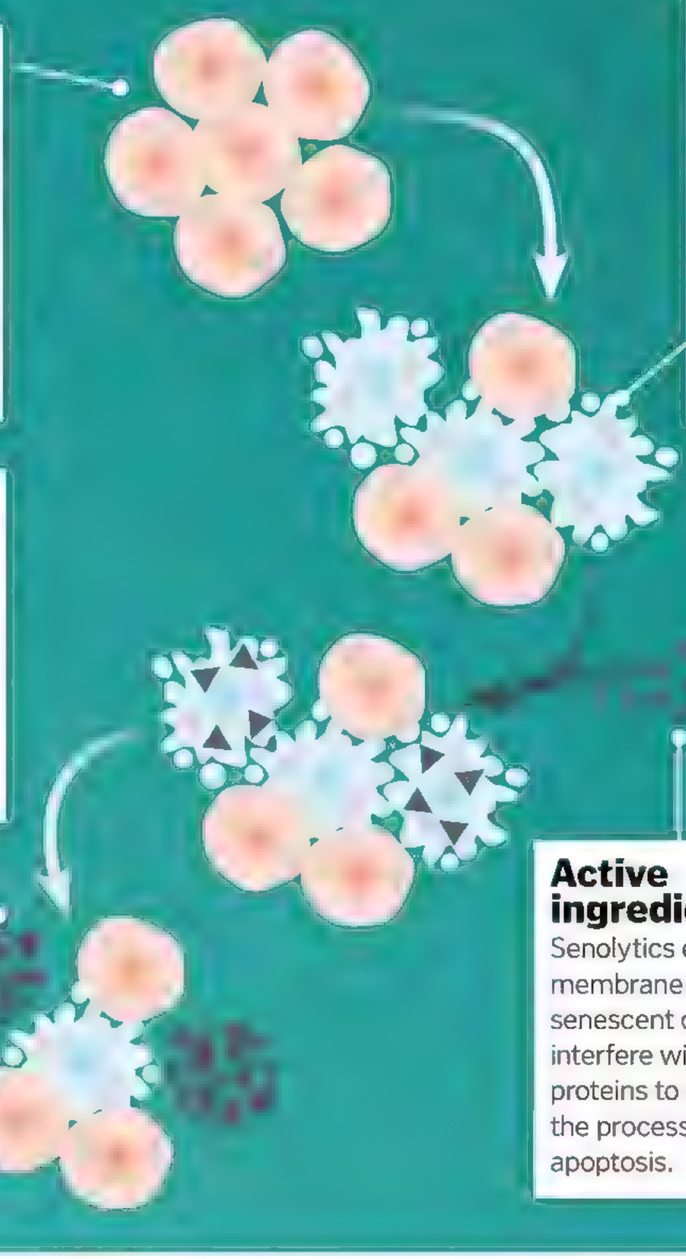
Anti-ageing pills

Could stopping the process of ageing be as simple as popping a pill? Researchers at the Mayo Clinic in Minnesota have been developing so-called senolytic drugs. These pills work by inducing apoptosis in senescent cells, preventing them from gathering. This prevents them from damaging neighbouring cells and causing age-related illnesses. So far this type of time-halting medicine has only been successfully trialled with animal subjects, though human trials are underway.

Senolytic drugs are not yet available, but could one day revolutionise the way we age

Inducing self-destruction

How senolytic drugs could keep us young



Normal tissue
Senolytic drugs are designed to only induce cell death in senescent cells, preventing them from causing tissue damage.

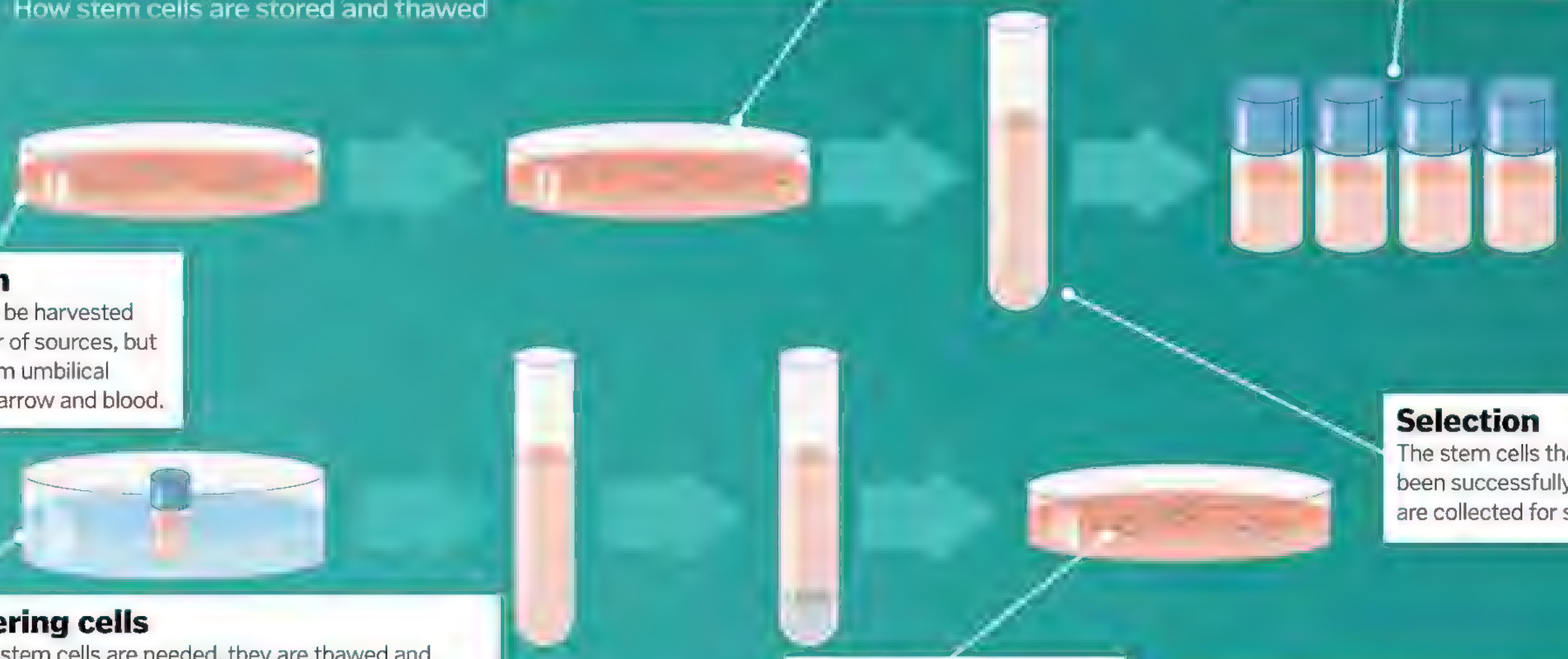
Senescent cells
These release inflammation-causing molecules that contribute to the development of age-related diseases such as cancer and osteoporosis.

Cell death
Once kicked back into gear, apoptosis breaks apart the cells, which will later be hoovered out by the body's immune system.

Active ingredient
Senolytics enter the membrane of the senescent cells and interfere with proteins to kick-start the process of apoptosis.

Freezing the future

How stem cells are stored and thawed



Collection
Stem cells can be harvested from a number of sources, but commonly from umbilical cords, bone marrow and blood.

Incubation
All of the stem cells are separated and incubated with inhibitors to stop them undergoing apoptosis. This also increases their chance of survival when they thaw.

Freeze
The vials of stem cells are placed in liquid nitrogen storage tanks until they are needed.

Selection
The stem cells that have been successfully inhibited are collected for storage.

Recovering cells
When the stem cells are needed, they are thawed and diluted. These can now be reinfused into the patient's body.

Healthy cells
Once prepared and cultured, the stem cells can be injected into the patient, where they travel to the bone marrow and start producing healthy cells.

Stem cell security

One way people are clinging to the hope of eternal youth is by cryogenically freezing their stem cells. Stem cells are special cells that can transform into any other type of cell in your body. By storing these cells, the hope is that one day they can be used for treatments to battle any future illnesses.

Currently the only stem cells used to treat conditions are those that change into blood cells for transplants in blood cancer patients. These cells can be harvested from sources such as the umbilical cord at birth, adult bone marrow or fat tissue. The cells are then frozen and stored for future use.

Young blood myth

People have gone to extreme lengths to preserve their youth, both cosmetically and biologically. However, in February 2019 the US Food and Drug Administration cautioned the public about receiving blood transfusions from young people in attempts to turn back the biological clock, saying that this had "no proven clinical benefit". Transfusions were being offered by companies such as California start-up Ambrosia, with a price tag of $8,000 (around £5,780) per litre of blood plasma – the liquid component of blood – from people aged between 16 and 25 years old. Claims that the protein-filled plasma could help with ageing-related ailments and diseases, such as inflammation and Alzheimer's, have not been substantiated by a great deal of scientific research, with limited studies investigating if the vampiric therapy provides any health benefits.

Pure oxygen and a pressurised chamber could be the key to unlocking a long life

Breathing young

A recent study conducted at Tel Aviv University has revealed that hyperbaric oxygen treatments could halt the ageing process. Over a research period of 90 days, 35 participants over the age of 64 were given hyperbaric treatments, which involved inhaling pure oxygen in pressurised environments for 90 minutes a day, five times a week.

Blood tests showed that the bodies of the participants changed on a cellular level to what they would have been like 25 years earlier. Researchers found that telomeres lengthened by 38 per cent, and a 37 per cent decrease in the presence of senescent cells. More research is needed to fully understand how hyperbaric treatments may intervene in the process of ageing, but it's a promising start.

AR ZONE!

IMMORTALITY

Is the future of everlasting life cryonics?

AR ZONE! SCAN HERE

One way in which you could give yourself the opportunity to live even after death is with cryonic suspension. It may have been able to bring back Austin Powers after 30 years of suspension, but beyond the world of science fiction, the practicalities of cryonics remain a mystery. Right now we have the technology to cryogenically preserve a human body, but remain clueless on how to revive them when the time is right. It's the belief that humankind will one day find a way to successfully thaw patients and treat whatever illnesses led to their death. The world leader in cryonics, Alcor, currently has 181 patients and has been storing humans for 49 years, including the company's founder, Fred Chamberlain.

The process of preserving a human body through cryonics involves replacing the water content of a body with a chemical cryoprotectant, which works like antifreeze. This is to prevent ice crystals forming during freezing and irreversibly damaging the body. Once filled with cryoprotectants, the body will eventually be placed into a tank of liquid nitrogen at around -196 degrees Celsius, where it will be stored.

Currently the biggest challenge of cryonics is to find out how it can allow people to be brought back to life. Science has successfully frozen simple cells such as eggs and sperm in suspension and thawed them with their functions intact. However, the same can't be said for the entire body. It remains unclear as to how scientists will bring back an entire, functioning human body. So far the only success scientists have had has been in bringing functionality back to the cryogenically frozen brain of a small rabbit.

We've got the science to safely cryopreserve the dead, but we're still unsure how to revive them

James Bedford was wrapped in several layers of aluminium foil to maintain his temperature

© Getty

First cryogenic human

The first person to ever be cryogenically frozen was Dr James Bedford, a 73-year-old psychologist who died of cancer. In 1967, Bedford entered a cryogenic storage dewar, a special vacuum flask to store super-cold cryogens such as liquid nitrogen. Upon his death, Bedford's blood circulation was artificially maintained while he was being cooled. His body was injected with dimethyl sulphoxide, which can preserve tissue, before being moved to a liquid-nitrogen environment. It's since been found that this method of preservation will have most certainly damaged the cells in Bedford's brain beyond any possible repair. Nevertheless, his body remains on ice at the Alcor Life Extension Foundation to this day.

Inside the cryo coffin

Preparation
The body is packed with ice and injected with a blood-thinning drug called heparin to prevent the blood from clotting before being transported to a cryogenic facility.

Artificial breathing
Within minutes of death, the body has to be put onto a mechanical heart-lung ventilator to keep the brain supplied with oxygen.

Cryonic chamber
Up to six bodies are held in a tank of liquid nitrogen, which reaches and is maintained at around -196 degrees Celsius.

Human antifreeze
A cocktail of chemicals is injected into the body to act as 'human antifreeze', replacing any water content in the body to prevent the formation of ice crystals.

Chill out
The body is then placed on dry ice and cooled until it reaches around -130 degrees Celsius.

DEATH

COOLING

HEPARIN

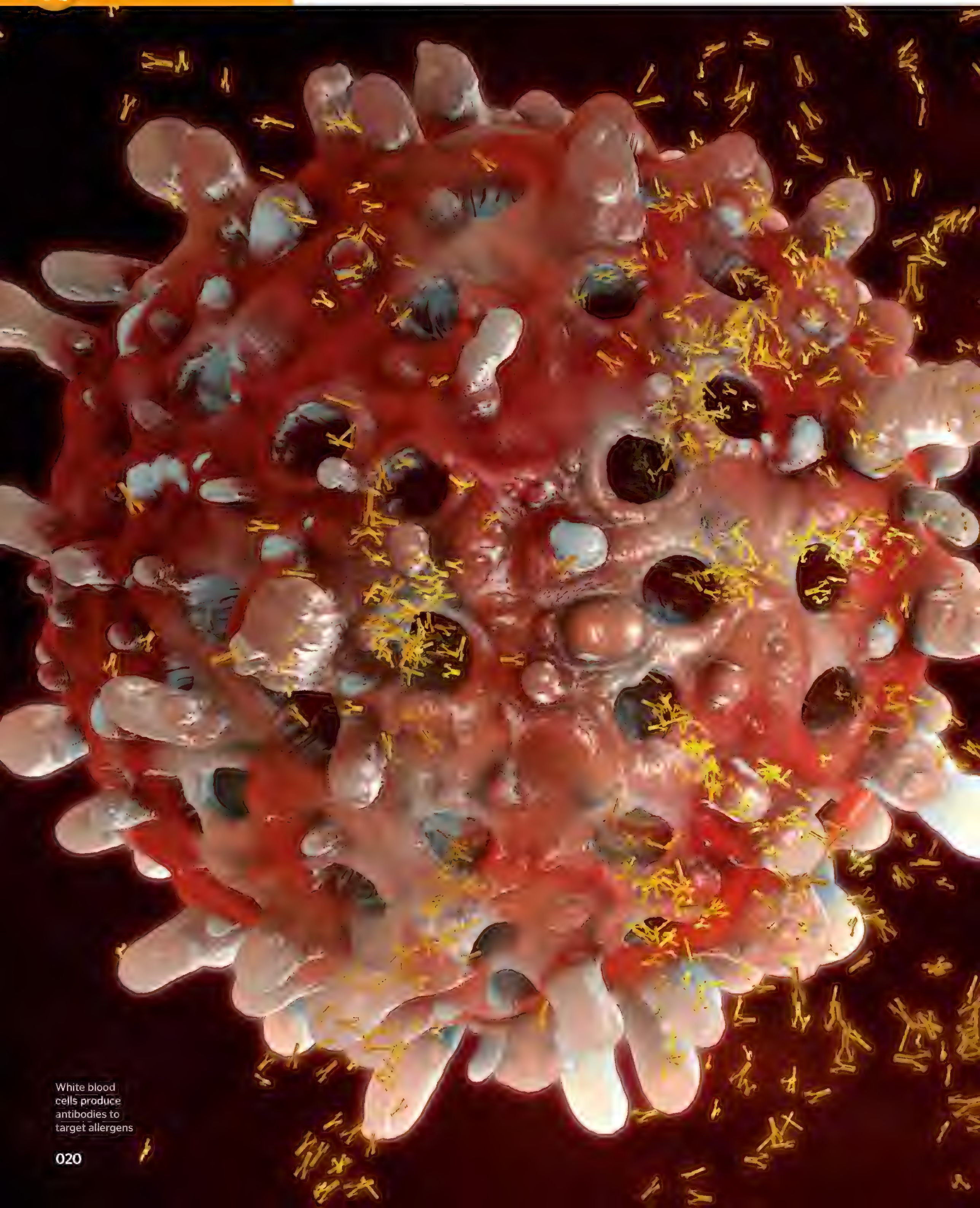
ANTI-FREEZE

CONTAINER

FREEZING

AR ZONE! SCAN HERE

Illustration by: Adrian Mann



White blood cells produce antibodies to target allergens

ALL ABOUT ALLERGIES

Sneezing, swelling and worse: what happens when your immune system goes into overdrive?

Words by **Ailsa Harvey**

Our bodies are constantly reacting to their surroundings. When it gets cold, your muscles work to warm you up. When you need food your stomach rumbles to alert you. When bacteria or viruses enter your body, cells instantly recognise them as harmful intruders to target.

The latter is performed by your immune system, a preprogrammed defence system consisting of organs, cells and proteins that is active throughout your entire body. As well as detecting threats to physical health, the immune system can sometimes become overactive, triggering an unnecessary response to non-toxic substances. This is how allergic reactions arise.

Every cell in your body has antigens. These are proteins that identify the cell and brand it as friend or foe. Our bodies use these to decide which cells to ignore and which to attempt to destroy or flush out of our bodies. An example of those that are usually ignored by the immune system are the cells of food products. We need food to remain in our body to provide us with energy and nutrition. But for some people this isn't always the case.

If you are allergic to an item of food, it won't take long to discover that your body doesn't welcome it. Your immune system will often first react towards the apparent invader when the allergen touches your mouth, likely causing you to feel pain or discomfort. Having wrongly identified a particular substance as a threat, proteins called antibodies are sent to locate the offender, attaching to it. When connected these antibodies act as a signal to other immune cells to show them where the danger is. During this process, histamine is produced. Histamine is the chemical responsible for the persistent symptoms you experience during an allergic reaction. The result of this chemical depends on the location it is released into.

Just as the allergen can vary enormously, so can the body's response. While some people's allergies are an inconvenience, for others they are life-threatening. One aspect that can make reactions so deadly is that to most

WHAT IS ANAPHYLAXIS?

Some people's allergic responses are a seasonal inconvenience, but for others they are much more dangerous. Allergies can be severe and even life-threatening when not managed and responded to hastily.

Anaphylaxis is a severe response to an allergen. One in 1,000 people may experience this type of reaction, where a sudden allergic reaction can escalate quickly. When the body reacts to the allergen, a surge of chemicals puts the body into shock. This can result in a drastic drop in blood pressure or narrowing airways – or both – and these can result in unconsciousness.

To manage symptoms of an anaphylactic attack, sufferers are injected with adrenaline. Anaphylaxis sufferers carry an epipen with them at all times, which they use to inject this drug as soon as it's needed. Without a quick response, it can be fatal.

Epipens contain a drug which constricts blood vessels to reduce swelling and reverse an allergic reaction

people, allergens are usually harmless. For example, to most of us peanuts are simply a food source. They can be found in a wide variety of packaged foods, and many people would choose them at a supermarket. Because the threat is not a universal one, those who could be killed by being in close proximity to the nut have to have their wits about them at all times. Their allergy is always at the forefront of their mind, and through habit it becomes their first thought before they choose a snack.

Some milder allergies produce similar symptoms to your average cold, including the common effects of a runny nose and puffy eyes, so how can you be sure that what you're experiencing is an allergic reaction? One way to spot an allergy is to look for patterns in the appearance of your symptoms. For instance, if you find that every time you go outside in the summer you begin to sneeze, this could be a seasonal hay fever allergy. Meanwhile, if you begin to feel itchy every time you play with your friend's dog, you are likely to have an allergy to its dead skin, saliva or urine – not its fur.

Our understanding of the science behind allergies has improved through research, but our complex immune systems are unique to every one of us. Even as early as the first century BCE, Roman philosopher Lucretius is quoted as saying: "What is food to one man is bitter poison to others." Luckily for today's allergy sufferers, there are ways to spot, diagnose and manage these anomalies in our bodies' defences and ensure that our immune systems, designed to save our lives, are less likely to do the opposite.

> "While some allergies are an inconvenience, for others they are life-threatening"

HOW DOES THE BODY RESPOND TO AN ALLERGEN?

1 Allergen entry
An antigen, such as pollen, specific foods or any substance that an individual is allergic to, enters the body. These cause the release of signalling chemicals called cytokines.

2 Antibody production
The cytokines alert the white blood cells to the presence of allergens, causing them to produce antibodies that travel in the bloodstream.

3 Identification
Antibodies attach to mast cells, which are found in most tissues throughout the body. These cells are rich in histamine.

4 Binding
As the antigen comes into contact with the mast cells, they bind to the antibodies. This triggers the mast cell to release its contents.

5 Histamine release
Sent out to protect your body from the allergen, a chemical called histamine wreaks havoc in your body. Whether it is inflaming your skin, making you sneeze or demanding you to itch, this is your body attempting to rid itself of the allergen it has deemed a threat.

5 FACTS ABOUT UNCOMMON ALLERGIES

1 Money
Sometimes occurring days after handling coins, it's possible for money to trigger a response. This is a nickel allergy. Sufferers may also need to limit contact with jewellery, door handles and some metal accessories.

2 Water
This rare condition, called aquagenic urticaria, gives sufferers an itchy rash when water touches their skin. With water being essential to life and with no effective treatment, water allergies can only be soothed with medical creams.

3 Vibrations
Vibratory urticaria is a condition which makes someone respond to any vibrating movement with rashes, headaches and face flushes.

4 Exercise
Although people joke about being allergic to exercise, for some it's a reality. This ranges in severity, but rigorous movement can bring on anaphylaxis in some. In these cases any form of exercise shouldn't be carried out alone, and medical supplies need to be at hand.

5 Human touch
If you have dermographism, your body's reaction to touch can be so instant that you could write on your skin with just the light touch of your own finger. The exact cause isn't known, and so there is currently little treatment available.

ALLERGY TYPES

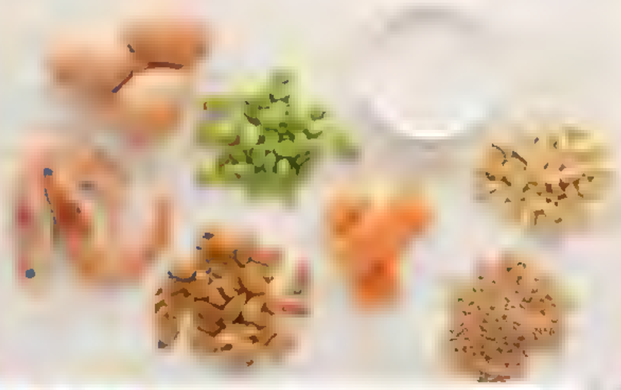
From our outer surface to internal organs, where does the immune system target?

SKIN IRRITANTS

There are multiple ways that your skin can react to a number of allergens, with different patterns, lumps and sizes of rashes. Skin is usually the first part of your body that everything in the outside world can reach. When your body doesn't agree with an antigen that has reached the skin, it will sometimes display its disturbance with a rash. The most common type of skin allergy is contact dermatitis. This is a type of eczema which causes the swelling, bumps and rashes that can instantly occur from contact with an allergen.

This rash of large bumps, called hives, most commonly occurs during food and drug allergies

Most food allergies are caused by these eight foods



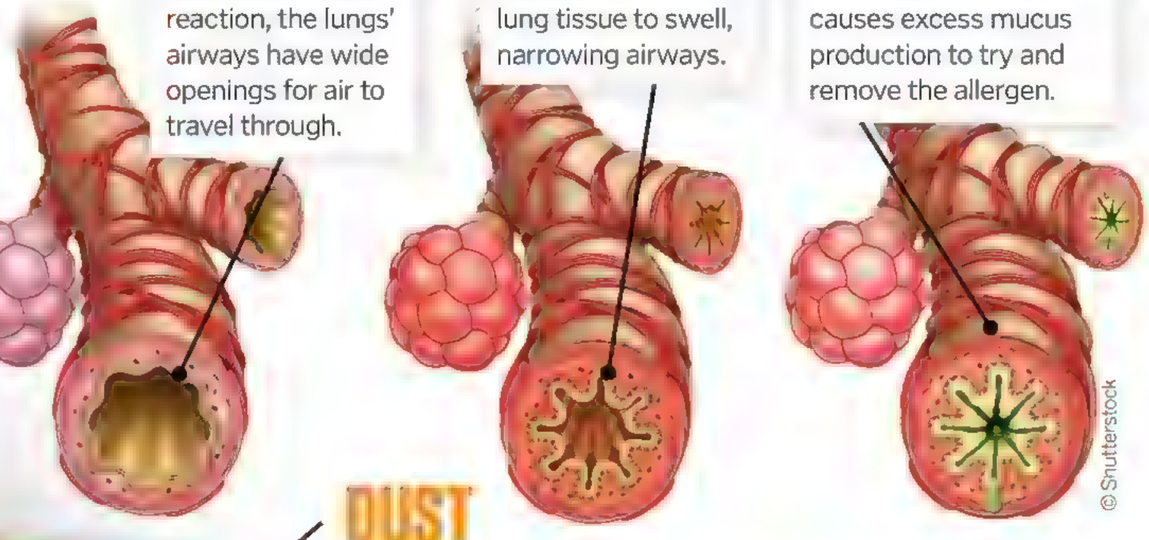
FOOD

Food is essential for life, but for some people certain foods can pose a threat. 90 per cent of all allergic reactions caused by food are a result of consuming eggs, milk, peanuts, tree nuts, fish, shellfish, wheat and soy. Reactions to food allergens vary drastically, but they include swelling of the tongue, face and throat, feeling sick, abdominal pain and tingling in the mouth. These responses can begin within a few seconds of the food touching the person's mouth.

POLLEN

You can tell when summer is approaching from the warming weather. If you have hay fever, your body gives you other telltale signs. Your eyes begin to water, your nose starts to run, headaches become a common occurrence and your eyes, nose, ears and throat produce an aggravating itchy sensation. Flowers increase their pollen production as the summer season approaches, meaning that this seasonal allergy is most common between the months of March and September.

Antihistamine medication can help relieve hay fever symptoms



Before an allergic reaction, the lungs' airways have wide openings for air to travel through.

Histamine causes lung tissue to swell, narrowing airways.

The allergic reaction causes excess mucus production to try and remove the allergen.

DUST

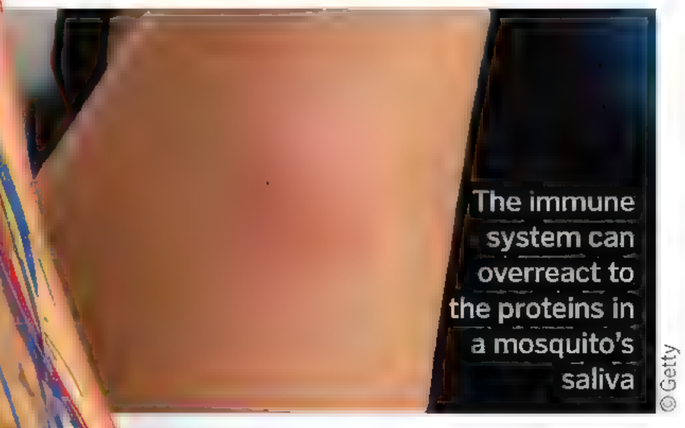
Inhaled allergies are the most common. Because the allergen is found in the air, it is often unavoidable and can easily enter the body. When breathed into the lungs of someone who is allergic, house dust, mould spores and proteins from animals can all irritate the airways of the lungs and induce asthma. This can make the individual wheeze, cough and feel breathless.

DRUGS

Medication is designed to help the human body, but each body is different. A drug that will cure one person could have adverse effects on another, with the most common signs being fevers and rashes. Antibiotics such as penicillin are the most common culprits, with up to ten per cent of people being told they have this allergy. A drug allergy needs to be documented on an individual's medical records.

INSECTS

When an insect bites or stings, redness and soreness are common. Some insects have defence mechanisms designed to cause you pain, so how do you know if your body's response to an insect's attack is standard or an allergic reaction? An allergic response is more severe, causing abnormal swelling or soreness. Often these are in other areas of the body away from the targeted area. If your face begins to swell up, you feel light-headed or you have difficulty breathing following a bite or sting, it is likely that you are having an abnormal reaction.



The immune system can overreact to the proteins in a mosquito's saliva

HOW TO DIAGNOSE AN ALLERGY

SPOTTING THE SYMPTOMS

What are some of the main signs of an allergy?

Breathing difficulties

A tight chest and shortness of breath can be indications of an allergy. Your immune system can sometimes respond by narrowing your airways. This inflammation in the lungs can cause wheezing, restricting the air travelling through your lungs.

Sudden sneezing

It is common for allergens entering the nose to cause inflammation. This response, from the likes of pollen, dust and pets, affects one in five people in the UK. Sneezing and a runny nose can be your body trying to send the antigen back out from where it entered.

Swollen face

Your face can swell up for many reasons, with some caused by allergens. The skin around the eyes puffs up when the eyes are suffering from allergies such as allergic conjunctivitis. The face might swell after food reactions, drug allergies and during anaphylaxis.

Stomach pains

As part of some food allergies, a cramping stomach pain can occur immediately after eating the offending food. This is because histamine is released inside the intestines or stomach, commencing an attack on the allergen inside these organs.

Change in skin

As our outer layer, skin is our body's first chance to defend itself from danger. One common skin response to an antigen are hives. These are itchy and raised reddened areas of skin and could be an indication of a food, drug or insect allergy.

Closing throat

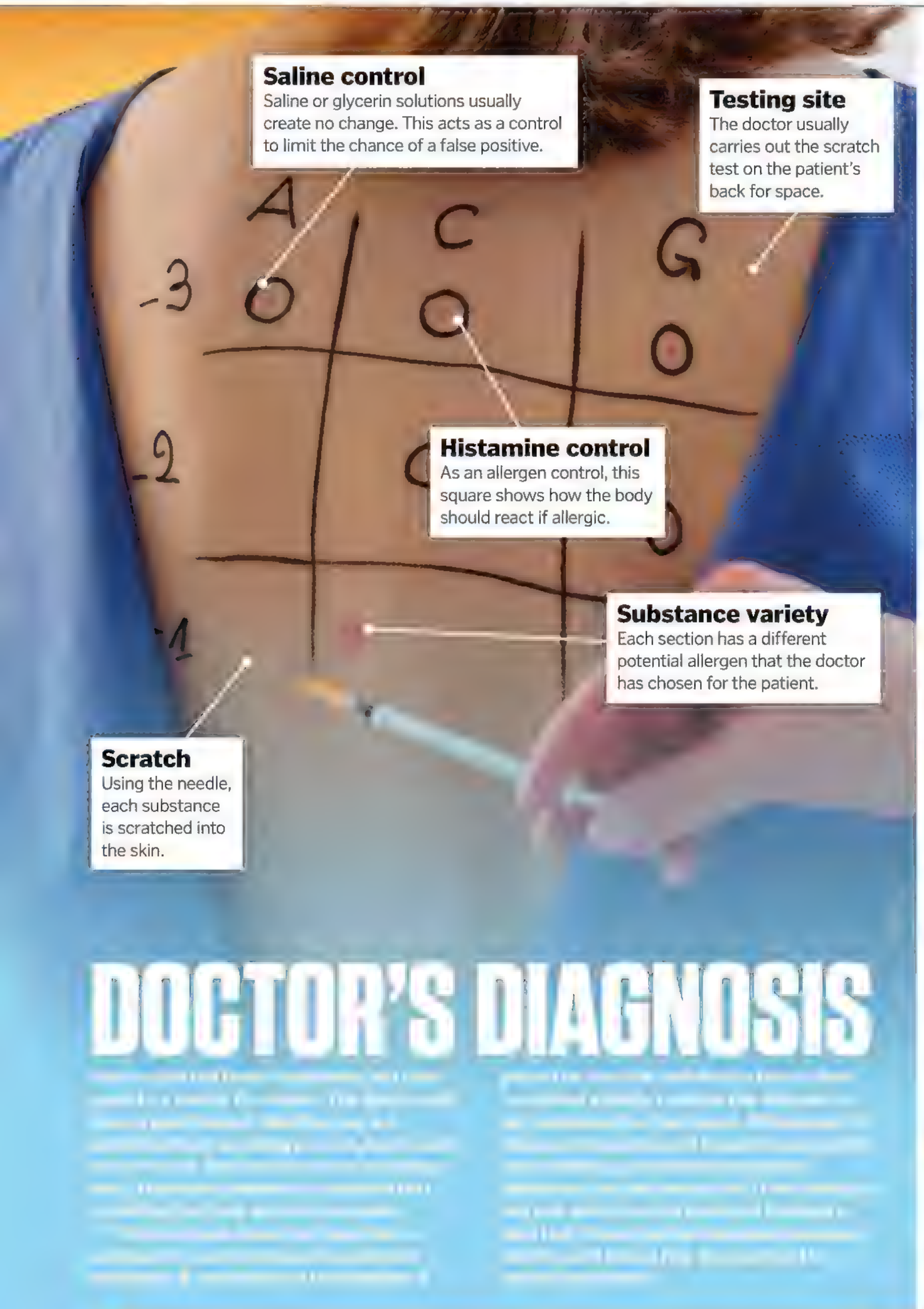
If your throat begins to feel tighter, this could be a severe allergic response. The feeling of a tight throat can range from it feeling swollen and sore to like having a band around your neck or an internal blockage, making breathing harder.

FOOD ALLERGY VS INTOLERANCE

How can similar reactions to food products be told apart?

ALLERGIC REACTION	INTOLERANCE
10%	**20%**
One in ten people are allergic to at least one food product.	At least twice as many people have a food intolerance.
FOOD ALLERGIES CAN OCCUR WITHIN SECONDS, SHOWING SIGNS WITHIN TWO HOURS	**IT CAN TAKE UP TO TWO DAYS FOR AN INTOLERANCE TO DISPLAY SYMPTOMS**
IMMUNE SYSTEM INVOLVED	**IMMUNE SYSTEM NOT INVOLVED**
Allergies occur when the immune system wrongly mistakes a type of food for a threat and tries to fight against it.	When the immune system is not alerted, the areas affected are more limited. Gluten intolerance is the only exception.
DEADLY TRACE	**VOLUME FLEXIBILITY**
Any amount of a food allergen can cause severe reactions – sometimes even being near the food.	Different people are able to consume different amounts before they show symptoms of intolerance.
HIGH RISK	**LOW RISK**
Severe allergies can lead to unconsciousness and become a risk to life.	Affected areas are limited to the digestive tract.
OVERACTIVE	**UNDERACTIVE**
The body undertakes extra and unnecessary work trying to fight off the allergen that it wrongly perceives as a threat.	Intolerances are often a result of a lack of enzymes to break food down. Without these the body is less active than it needs to be.

"Look for patterns in the appearance of your symptoms"



DOCTOR'S DIAGNOSIS

MISDIAGNOSIS

Allergy symptoms can often overlap, sometimes making it difficult to be certain of what is causing the reaction. Some people are so eager to find a treatment for this irritation that they self-diagnose themselves incorrectly.

This often happens during the winter months, when chances of congestion increase. With the common cold closely imitating the symptoms of allergies, the two can be confused. In many cases self-diagnosis stems from sinusitis, which involves the sinuses swelling to produce pain in the face and congestion. Even medical experts have been known to get this wrong.

For those who have been given a false-positive diagnosis, sometimes it makes no difference. But sometimes the patient will avoid beneficial medicines such as penicillin, missing out on an antibiotic that is often the most effective cure. Others whose true allergens aren't recognised may continue to be exposed to the allergens that are causing their suffering. It's important to keep an eye on your allergies and seek further testing if you think you have been misdiagnosed.

A misdiagnosis of a food allergy can compromise an individual's diet

© Getty

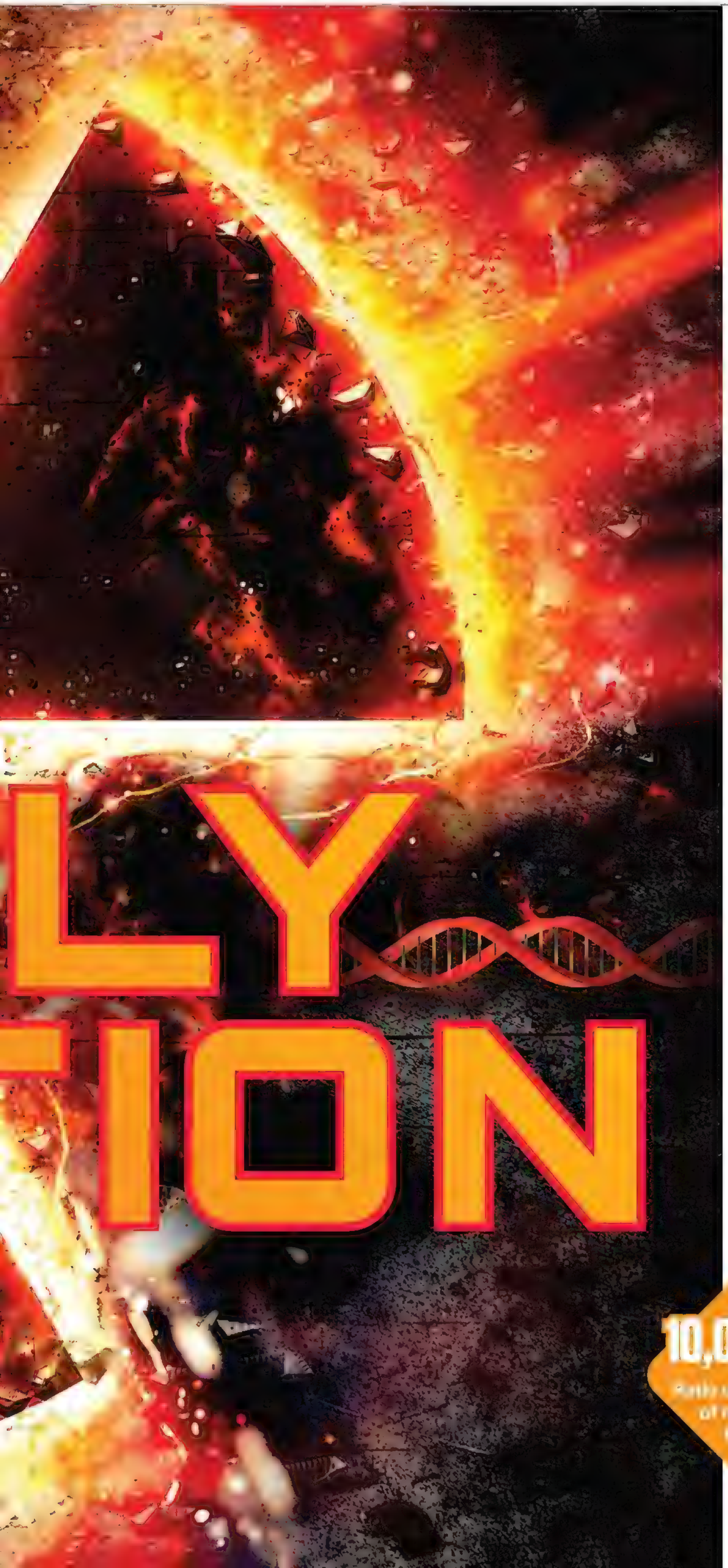
AT-HOME ALLERGY TESTS

If you are worried that you are suffering from allergic reactions, seeking the help of a medical professional is the way forward. There are also some at-home tests that you can buy. These claim to be able to tell you your allergies by analysing a small amount of blood that you post to the laboratory.

Children usually need a medical professional to take their blood, but adults are just required to prick their finger and wait for their results. Although these tests have been shown to be a good indicator of some allergies, they actually only inform you of the allergens you are sensitive to by detecting levels of the immunoglobulin antibody. For a proper diagnosis, you then need to be tested through your doctor.

Home kits can be sent straight to a laboratory, where your blood is tested for antibodies

DEAD RADIATION



FROM DENTAL X-RAYS TO NUCLEAR REACTORS: EVERYTHING YOU NEED TO KNOW ABOUT IONISING RADIATION, ITS USES AND HAZARDS

Words by **Andrew May**

For many, the word 'radiation' can set alarm bells ringing. If you think of the terrible death toll of the Hiroshima and Nagasaki bombs, or the devastating environmental effects of the Chernobyl nuclear disaster, it's easy to see why. Events like these show just how lethal radiation can be. But radiation is around us all the time – most of it completely harmless, and much of it positively beneficial.

In its broadest sense, radiation refers to any form of emitted energy that travels outwards – or radiates – from a source. It can take the form of streams of fast-moving particles, such as those emitted by radioactive materials, or of the electromagnetic (EM) waves generated when electrons jump from one energy level to another inside atoms. The heat and light we receive from the Sun come to us in the form of EM radiation, and life on Earth would be impossible without these particular forms of radiation.

There are other types of EM radiation that we can produce by technological means, such as radio for communication, microwaves for cooking or X-rays for medical imaging. Although these are created and used in different ways, they are all essentially the same type of wave, travelling from A to B at the same speed – the speed of light. The difference lies in wavelength and frequency. EM radiation has a spectrum ranging from radio waves at the low frequency, long-wavelength end to X-rays and gamma rays at the high frequency, short wavelength.

10,000,000
Ratio of wavelengths of microwaves to X-rays

Any kind of EM radiation can be dangerous if enough energy is pumped into it. You see hazard warnings on microwave ovens, for example, and on lasers – which are

Hans Geiger (left) with Ernest Rutherford, who named alpha, beta and gamma radiation

simply an intense beam of light. But there's a subtlety which makes the high-frequency end of the EM spectrum substantially more dangerous than the lower end. This stems from the fact that EM radiation is fundamentally bipolar – the so-called 'wave-particle duality'. Although it travels from its source to its destination exactly as if it were a wave, when it gets there it passes on its energy as if it were packaged up in discrete particles, called photons. The higher the frequency, the more energy each photon carries. If you have a microwave beam and an X-ray beam with the same total energy, the microwave energy will be spread out over millions of times more photons.

The significance of discrete photons lies in the effect they have when they hit atoms at the receiving end. If there are a lot of low-energy photons, as in a microwave beam, they just cause the atoms to vibrate a bit more, which has the effect of increasing the temperature. The same is true of infrared radiation, which lies between microwaves and visible light in the spectrum, and is the principal way that the Sun heats the Earth. When you feel warm sunshine on your face, it's because the photons are causing the atoms to jiggle about just that bit more.

It's different on the other side of the visible spectrum, where we find higher frequency ultraviolet (UV) radiation. UV photons carry enough energy to produce internal changes in atomic structure, boosting electrons to higher energy levels and altering molecular bonds. This can potentially cause DNA damage, which is

"THE EARTH IS UNDER CONSTANT BOMBARDMENT FROM COSMIC RADIATION"

400x
Radioactivity inten Dannevirke recorded by Beatrice Ho

Ten electronvolts
Minimum energy for a photon to ionise an atom

That spooky blue glow

Although ionising radiation is invisible, we sometimes see its effects on surrounding material. Old-style radioluminescent paint glows because it's slightly radioactive, stimulating light emission from the paint molecules. More spectacularly, water-cooled nuclear reactors emit an eerie blue glow called Cherenkov radiation. This isn't dangerous itself – it's just ordinary light – but it's caused by super-fast beta particles that would be harmful if they weren't absorbed by the water, which has a protective as well as cooling function.

The beta particles travel close to the speed of light, but paradoxically the light itself doesn't. That's because light slows down to three-quarters of its normal speed when it travels through water. The result is a shock wave – like the sonic boom caused by an aircraft travelling faster than the speed of sound – and that's what we see as the characteristic Cherenkov glow.

Cherenkov radiation surrounding the core of an underwater nuclear reactor

One of dozens of infamous atomic weapons tests at Bikini Atoll, 1946 to 1958. A fleet of dummy warships is overwhelmed by the blast

Nuclear tests 1945 to 1996

45 CHINA

45 UNITED KINGDOM

210 FRANCE

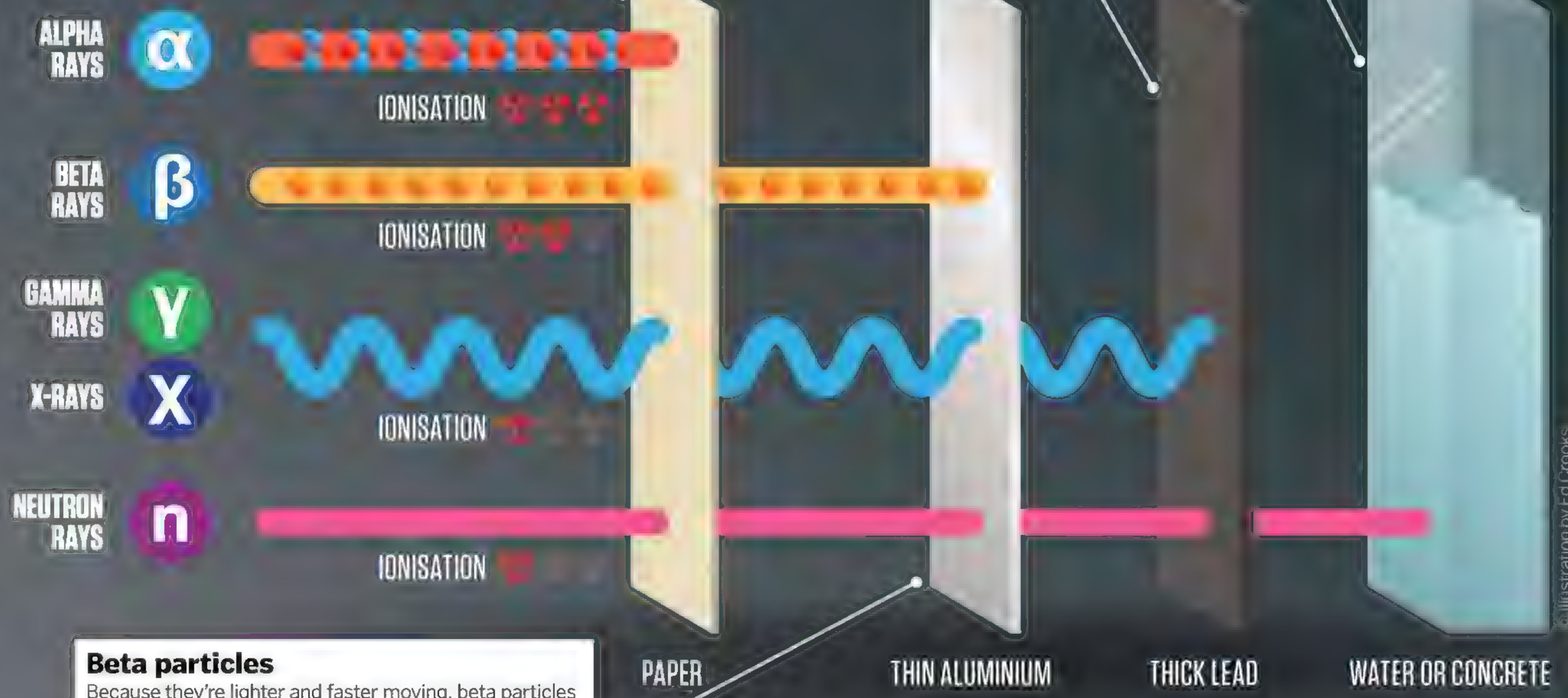
715 SOVIET UNION

1,032 UNITED STATES

The nuclear tests carried out during the 20th century added to background radiation levels

Radiation shielding

Some types of ionising radiation are easier to block than others



Alpha particles

Of the two types of particle radiation emitted by radioactive materials, alpha rays are the easiest to stop. A thin sheet of paper will do it – or, if you want to live dangerously, a human hand.

Beta particles

Because they're lighter and faster moving, beta particles have greater penetrating power. They pass through paper easily, but they can still be stopped by a sheet of aluminium just a few millimetres in thickness.

Gamma rays

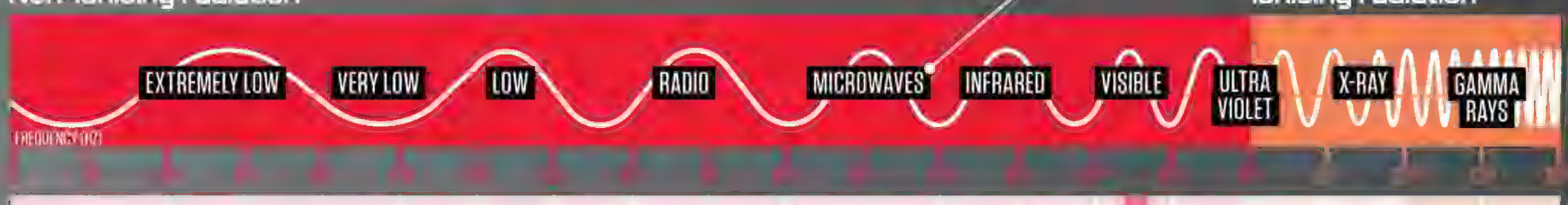
The third type of radiation emitted by radioactive substances is even harder to block, because it consists of EM waves rather than particles. But even gamma rays can be stopped by a few centimetres of lead shielding.

Neutron radiation

The fast neutrons created in a nuclear reactor are the hardest type of radiation to stop. Heavy elements like lead aren't as effective as light ones like hydrogen, so reactors are shielded by several metres of hydrogen-rich concrete or water.

The electromagnetic spectrum

The EM spectrum spans a vast range of phenomena and technologies



Microwaves

Most commonly associated with microwave ovens, these frequencies – corresponding to wavelengths of a few centimetres – are also used by communication systems such as mobile phones and Wi-Fi. It's at this point that overexposure starts to become hazardous.

Extremely low frequency

These frequencies are too low to have much practical use, since they only provide a bandwidth, or information-carrying capacity, of a few Hertz. Nevertheless, the fact that they can penetrate through water makes them useful in communicating with submarines. They're also produced by natural phenomena such as lightning.

Radio frequencies

At the lower end, used for AM radio, the bandwidth is still relatively small, so audio quality is poorer than in the higher frequency FM band. The top end of the range is used for TV broadcasting.

Infrared, visible and UV

This is the most familiar part of the EM spectrum, encompassing the bulk of the radiation we receive from the Sun. We feel infrared as heat, our eyes use visible light to see and UV – which is harmful if we're overexposed to it – is what gives us a suntan.

Ionising radiation

The hazardous potential of EM radiation comes to the fore here, as the photons carry enough energy to ionise atoms. There isn't much of it about, and it's controlled – whether in the form of X-rays from a hospital scanner or gamma rays from a nuclear reactor.

How radiation damages DNA

The health hazards of ionising radiation come from its effects on DNA molecules

Free radical
The free radical damages a DNA molecule in much the same way that a direct radiation hit would.

FREE RADICAL

WATER

RADIATION

RADIATION

Indirect effect
Radiation hits a water molecule and creates an unstable by-product called a free radical.

Direct effect
Radiation – a high-energy photon or particle – hits a strand of DNA, breaking it.

DNA damage
If a single strand is broken the DNA may repair itself, but more extensive, double strand damage is likely to be permanent.

An important use of X-rays is as a diagnostic tool looking inside the human body

1895
Wilhelm Röntgen discovered ionising radiation in the form of X-rays

why we have to wear sunscreen when UV levels are high.

As we go further up the frequency spectrum, we get to a point where individual photons have so much energy they don't simply boost electrons to higher levels inside an atom, they knock them out of the atom altogether. Because electrons carry a negative electric charge, this turns the atom into a positively charged ion. This process is referred to as ionisation. Radiation capable of achieving this is called – predictably enough – ionising radiation, and it's what people are really thinking of when they associate radiation with danger.

X-rays, which come above UV in the EM frequency spectrum, are an example of ionising radiation. They can cause DNA damage and other medical problems – but only if the amount received is high enough. In small doses, such as you might receive in a dental X-ray or hospital scan, there's nothing to worry about. In fact, the best known property of X-rays – that they travel through soft tissue as if it was transparent – has been a huge boon to medical science.

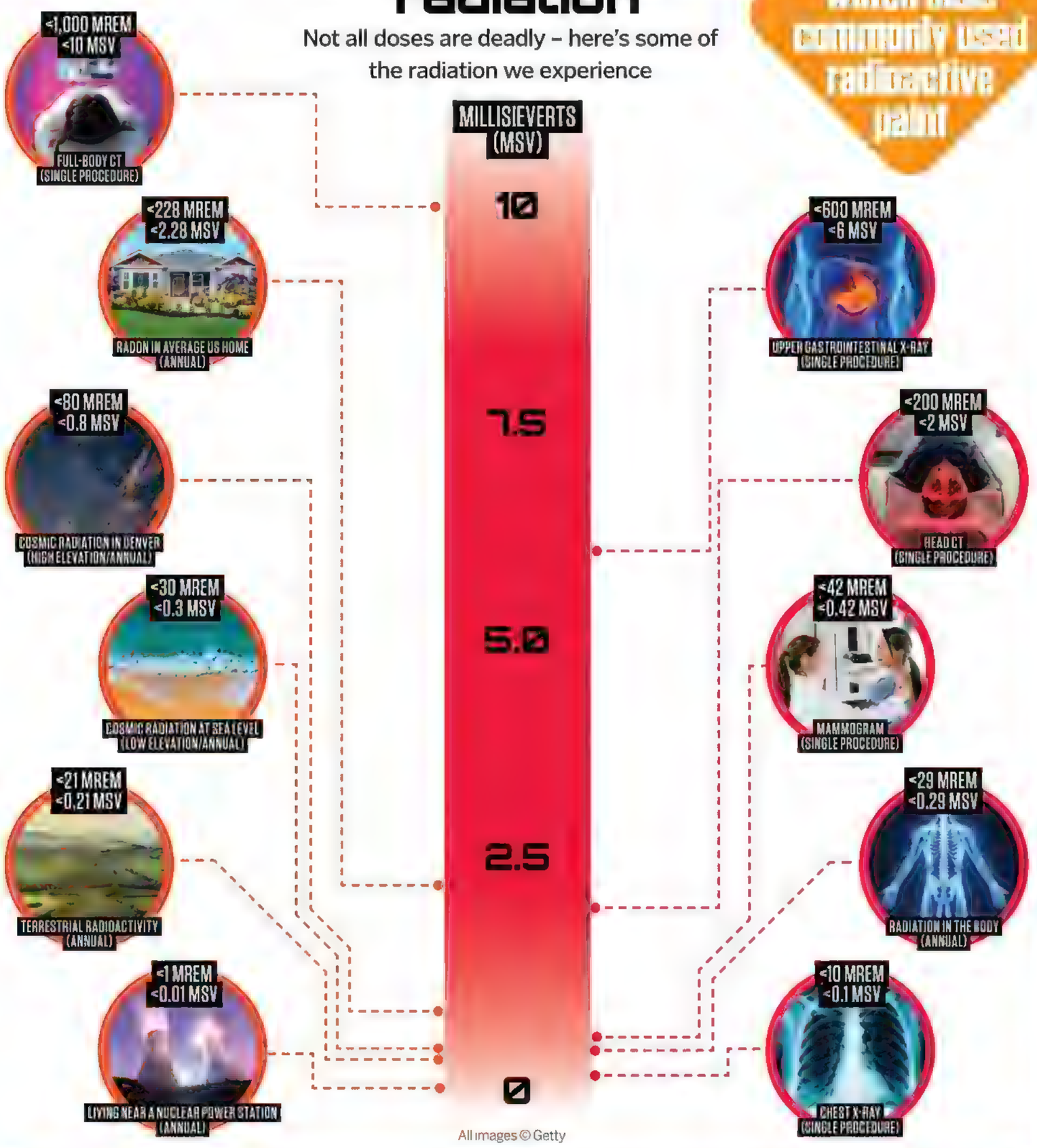
When X-rays were first discovered by physicist Wilhelm Röntgen on 8 November 1895, he gave them that name – 'X' for unknown – because he had no idea what they were. On the other hand, it was obvious right away that they were incredibly useful. The first recorded use of X-rays for a medical diagnosis was on 11 January 1896, just nine weeks later. That's the quickest that a brand-new scientific discovery has ever found a practical application.

X-rays are produced by electronic means, just as microwaves, light and UV can be. But when we get to the top end of the EM spectrum, the photon energies are so huge they can only be created by processes inside the atomic nucleus. This is the fearsome gamma radiation that's produced, among other things, by nuclear bombs. But gamma rays don't have to originate in a tremendous explosion. At a much lower level, they're given off spontaneously by certain elements that have unstable nuclei in a process known as radioactivity. Some radioactive elements can only be produced artificially – for example in a nuclear explosion or a nuclear reactor – but others occur naturally. These natural sources of radioactivity, of which uranium is the best known, are around us all the time, albeit in relatively small quantities.

Classical scholars will be aware that gamma is the third letter of the Greek alphabet after alpha and beta. So where do alpha and beta radiation come into the picture? They're also forms of ionising radiation given off by radioactive substances, but they're not part of the EM

Everyday radiation

Not all doses are deadly – here's some of the radiation we experience



All images © Getty

Even radio-frequency radiation can be hazardous right next to a powerful transmitter

Source Wiki/Tom Jennings

A century ago, luminous watch dials commonly used radioactive paint

Alpha and beta radiation

Unlike gamma rays, which are EM waves, the two other types of radiation emitted by radioactive substances consist of particles thrown out from unstable atomic nuclei. The nucleus is a dense clump of positively charged protons and electrically neutral neutrons. An alpha particle is composed of two neutrons and two protons, giving it a net positive charge and a relatively hefty mass. A beta particle is a fast-moving electron, which is much lighter and has a negative charge. Electrons are normally found in the outer parts of an atom, outside the nucleus, but beta particles are created by reactions inside the nucleus itself.

An early photograph, from 1915, of alpha particle tracks in a cloud chamber

Measuring radiation

From a health-and-safety point of view, it's important to know how much ionising radiation is present in an environment. The most familiar way to measure this is the Geiger counter, which simply counts the number of ionising particles reaching it. But this isn't the best indication of danger level because it doesn't distinguish between high- and low-energy particles. A more refined alternative is the electronic dosimeter, which measures the cumulative energy received from ionising radiation in units called sieverts, with a fatal dose being about eight sieverts. For comparison, a dental X-ray gives you about five-millionths of a sievert, while you normally get twice that in the course of a day from natural background sources of radiation.

A dosimeter being used to check radiation levels at the site of the Chernobyl disaster

spectrum. Rather than photons, they consist of streams of material particles: helium nuclei in the case of alpha rays and electrons in beta rays. What happens in radioactive decay is that an unstable nucleus spontaneously transforms into a more stable form, ejecting a photon or fast-moving particle in the process.

Alpha, beta and gamma rays were discovered in quick succession in the late 1800s and early 1900s, and were given their names by the 'father of nuclear physics', Ernest Rutherford. If you're interested in physics you've probably heard of him, but even if you aren't you'll be familiar with the name of one of his assistants at the University of Manchester, Hans Geiger. With Rutherford's help, he designed the first gadget for counting particles emitted by a radioactive sample. Geiger counters are still in use today, along with a range of more modern devices for measuring radiation levels – but the ominous clicks of a Geiger counter have become so familiar through movies and TV that the term is often used loosely for all such devices.

If Geiger counters had existed centuries ago, they still would have given off the occasional click. That's because there's always a low background level of ionising radiation from natural sources. Some types of rock, such as granite, contain tiny traces of uranium and other radioactive elements. The Earth is also under constant bombardment from cosmic radiation, emanating both from the Sun and from more distant parts of the universe. This includes fast-moving protons and other high-energy particles, as well as X-rays and gamma rays. But the amount reaching the Earth's surface is much too small to pose any health risks.

Since the second half of the 20th century, the level of background radiation has been boosted by nuclear weapons tests carried out between the 1940s and 1990s. The immediate radiation created by the explosions is long gone, but the blasts also produced a 'fallout' of radioactive material that has lingering effects to this day. The same is also true of the radioactive fallout produced by major incidents at nuclear power plants, such as Chernobyl in 1986 and Fukushima in 2011. These notoriously added to background radiation levels over a wide area.

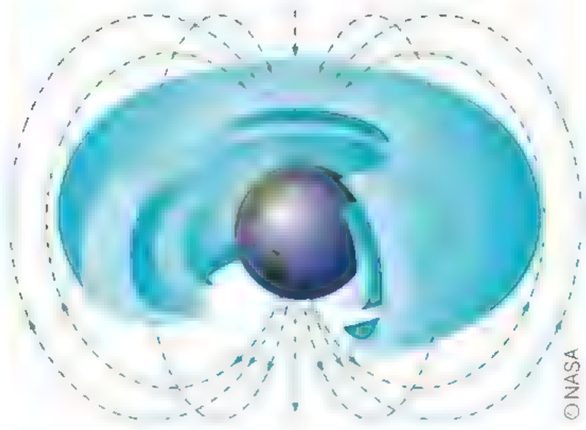
1 million
Number of dental X-rays needed for a fatal radiation dose

Given the enormous potential of nuclear power to reduce worldwide carbon emissions, it's a tragedy when accidents like these cause so much damage to the environment. But the fact is that both Chernobyl and Fukushima were the result of human error – compounded, but not caused, in the latter case, by an earthquake and tsunami. If a nuclear power station is properly designed and correctly operated, there's no reason why it should leak any radiation into the environment at all.

Radiation in space

While EM radiation travels in straight lines, that's not always true of charged particles, which can be deflected by magnetism. This has a welcome effect on Earth, because the geomagnetic field shields us from the high-energy protons and electrons constantly streaming out from the Sun. But not all of that radiation is bounced harmlessly back into space – some of it gets trapped in doughnut-shaped rings around the Earth. Called the Van Allen belts, these start well above the altitude of the International Space Station, but they do pose a potential hazard for astronauts passing through them en route to more distant destinations.

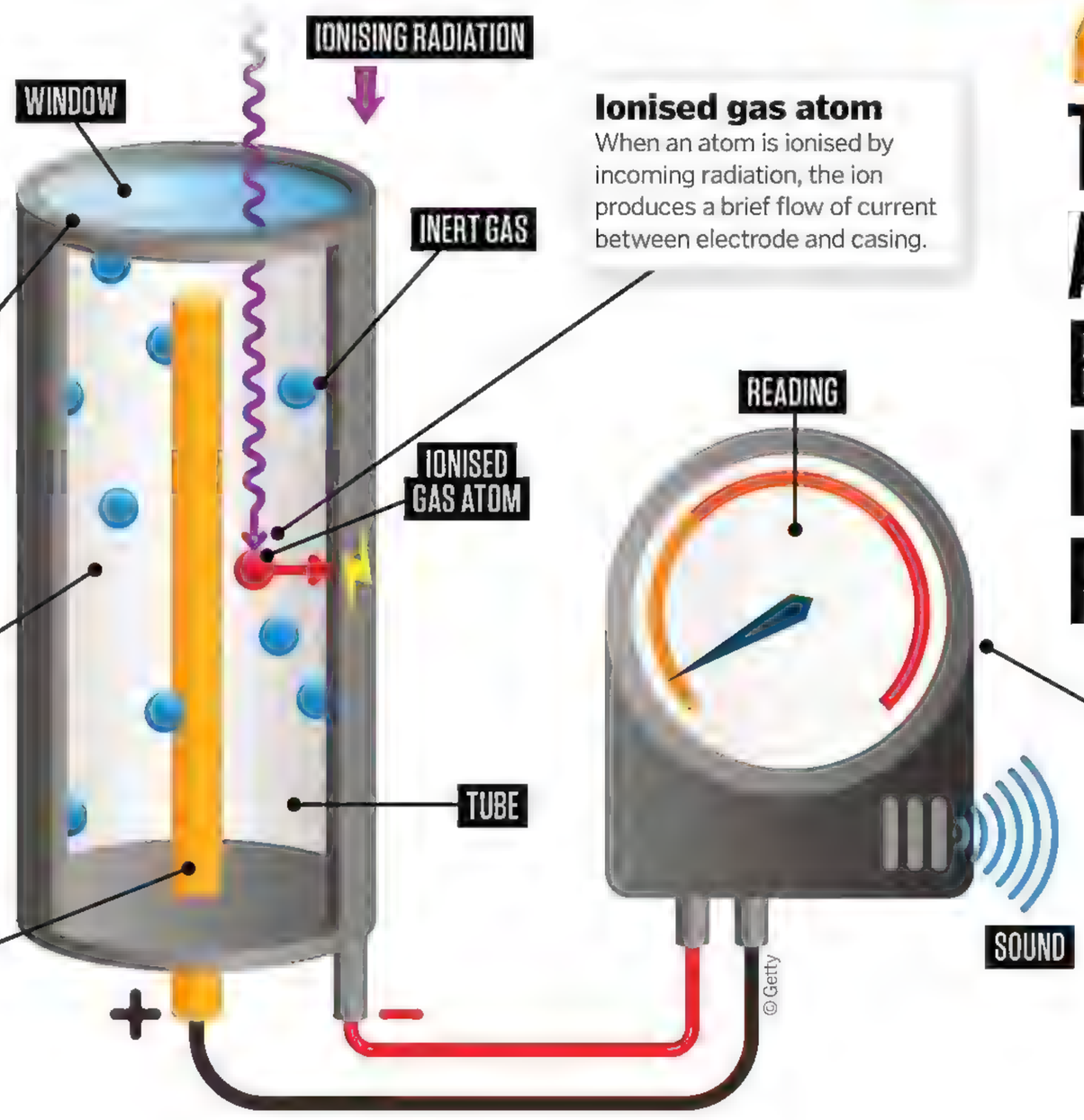
Fortunately, a fast-moving spacecraft will only be inside the belts for an hour or so. In the case of the Apollo astronauts, NASA estimates they were exposed to 0.16 sieverts on their passage through the radiation belts – a relatively high dose, but still only about a fiftieth of the fatal level.



The Earth's magnetic field traps radiation in the doughnut-like Van Allen belts

How Geiger counters work

The oldest way to measure ionising radiation uses that very same property



Ionised gas atom
When an atom is ionised by incoming radiation, the ion produces a brief flow of current between electrode and casing.

Mica window
The ionising particles enter through a thin mica window at one end of the tube.

Gas-filled tube
The main sensor consists of a metal-lined tube filled with an inert gas at low pressure.

Central electrode
Running through the middle of the tube is a metal electrode, held at high voltage relative to the casing.

Counter
The resulting electrical pulse is amplified to an audible click, and displayed on the meter at the same time.

> "THERE'S ALWAYS A LOW BACKGROUND LEVEL OF RADIATION"

Water is excellent at blocking radiation due to its hydrogen molecules. This is the Advanced Test Reactor in Idaho. It's submerged in water, generating the blue glow of Cherenkov radiation

Laser stands for Light Amplification by Stimulated Emission of Radiation

How the body makes blood

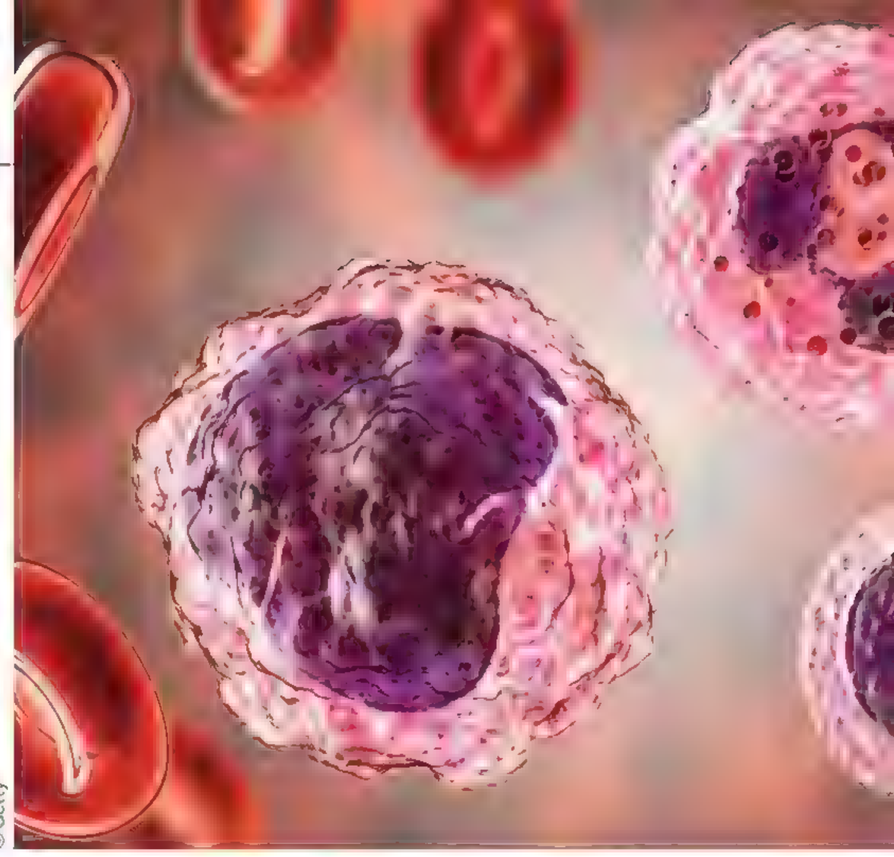
This life-supporting fluid is produced within our bones

Beneath our skin, blood circulates our bodies, distributing the oxygen and nutrients we require to stay alive. Although the blood pumping through us is constant, the blood cells that rush through our veins are frequently being replaced. Red blood cells only live for around 120 days, and with the possibility of losing blood unexpectedly in accidents, we routinely need new supplies. Luckily, our bodies have a way of creating plenty more of them.

Red blood cells don't have a nucleus, the part of a cell that controls functions and contains DNA. Without these genetic instructions, red blood cells can't make copies of themselves the same way that other cells do. Instead the body produces entirely new cells. It does this by modifying cells that do not yet have specific roles, called stem cells.

Blood cells are born from bone marrow. This soft, spongy tissue is home to stem cells, which have the potential to become any tissue cells the body needs. As well as producing blood, the body has to maintain and filter the cells it makes.

To ensure the right number of cells are pumping through blood vessels, old blood cells that are no longer needed are destroyed. Without this process, the regular manufacturing of blood cells would create blood that is too thick, and the body would be unable to keep it circulating.



© Getty

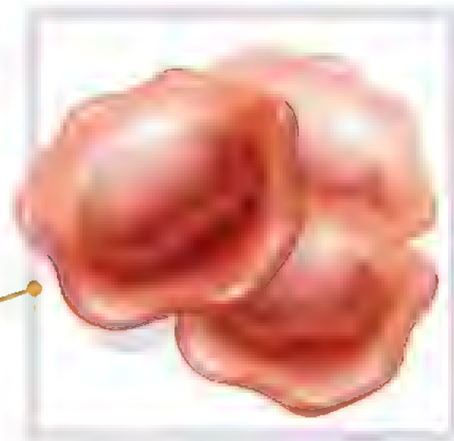
Some white blood cells only live for a matter of days, while others stay in the body for years

The production process

Discover how stem cells form the components of our blood

Bone marrow

Red blood cells, platelets and most white blood cells are made in the red bone marrow, one of two types of bone marrow.

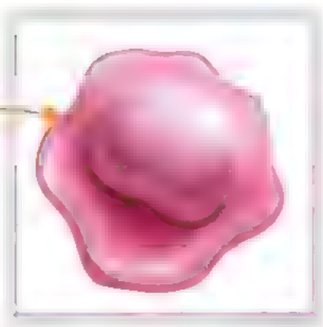


Stem cells

The stem cells that are used to make blood undergo their first specialisation, becoming myeloid or lymphoid cells.

Myeloid stem cells

These stem cells are responsible for making the majority of cells in blood. They can specialise further to form several other types of cell.

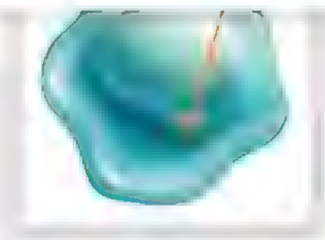


Red blood cells

These cells transport oxygen to the body's tissues. When at high altitudes with less oxygen available in the air, the body produces more of these cells.

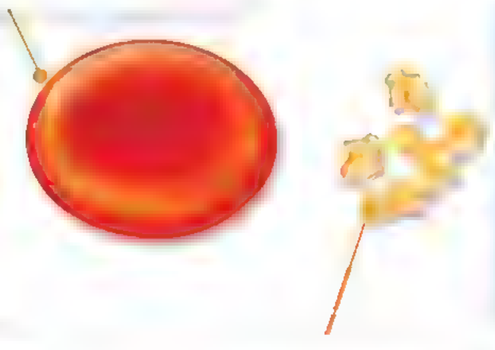
Lymphoid stem cells

Some of these lymphoid stem cells will travel to the thymus gland in the chest, where they will become T lymphocytes. The rest will produce B lymphocytes.



White blood cells

Myeloid stem cells can become either granulocytes or monocytes. Monocytes alert the body to foreign proteins on cells, while granulocytes act quickly to kill these cells.



Platelets

A normal platelet count ranges from 150,000 to 450,000 platelets per microlitre of blood. These colourless cells rush to injured skin to clot blood.

© Alamy

Lymphocytes

About 25 per cent of all white blood cells are lymphocytes. They make proteins called antibodies that can quickly identify and attack specific harmful cells.

5 FACTS ABOUT BLOOD REPLACEMENT

1 Production time
It takes about two days for a red blood cell to be produced.

2 By the millions
2 million red blood cells are produced every second.

3 Donating blood
When giving blood, an adult can donate one of the ten pints in the average adult body.

4 Replacements
It takes the body 48 hours to replace blood plasma and up to eight weeks to replace red blood cells after blood donation.

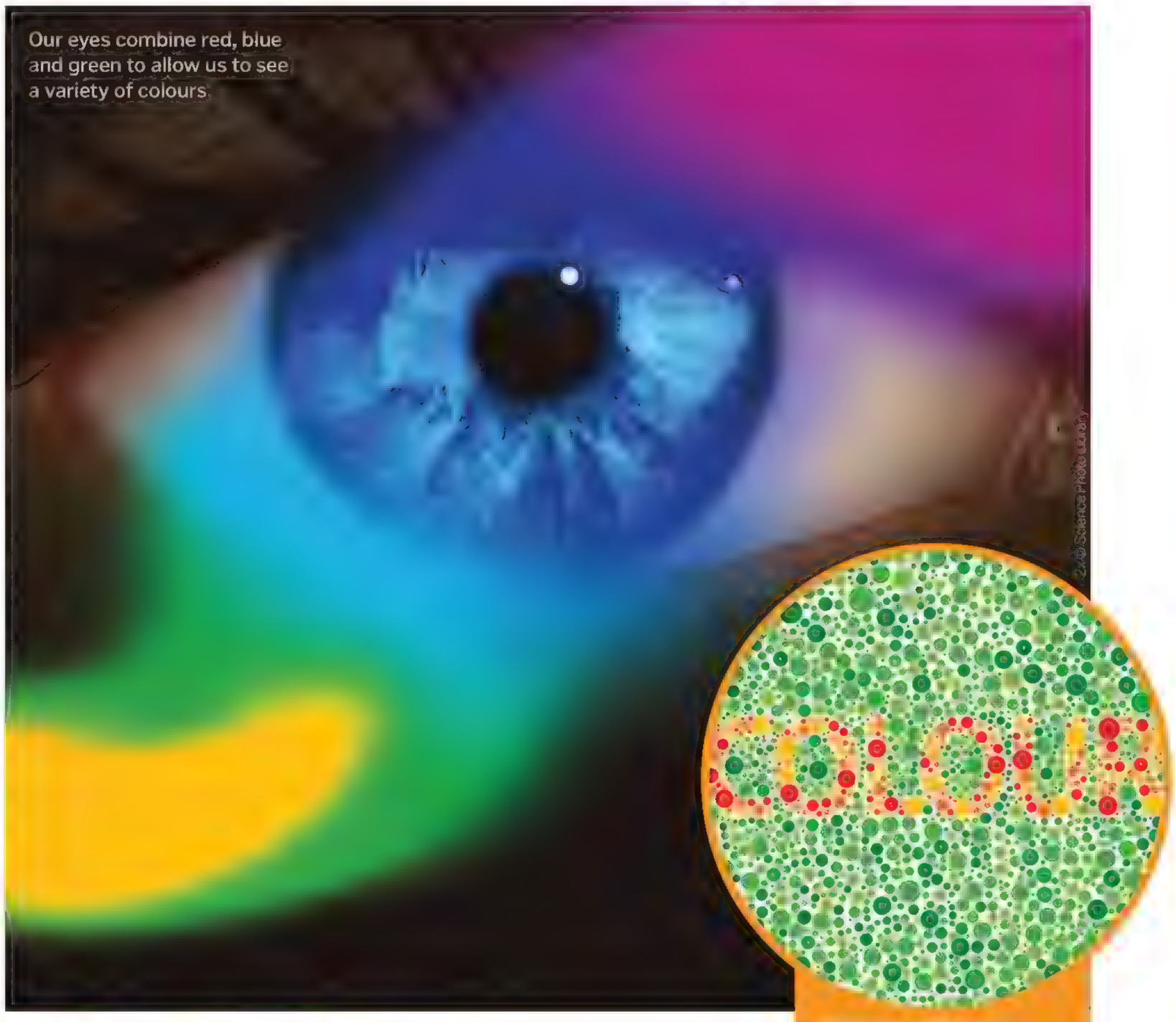
5 Pregnancy production
When pregnant, the volume of blood in the body can increase by up to 50 per cent, as the body and baby require more oxygen.

Light and colour

Why do we see things in colour, not black and white?

Light such as sunlight contains the full electromagnetic spectrum, but our eyes are only sensitive to a wavelength of approximately 390 to 700 nanometres (nm), known as visible light. As sunlight shines on an object, such as a green apple, the object absorbs some of the incident light – the direct light that hits the surface. However, it reflects a specific wavelength of light, in this case corresponding to the colour green, which is received by sensors in the eyes known as rods and cones. These tell the brain that the colour of the object is green.

White paper appears white because it reflects all visible light. We see black when all visible light is absorbed by an object. Certain pigments within an object will absorb light and define which wavelengths they will emit. The primary colours of red, blue and green combine to create the many different colours that we see.

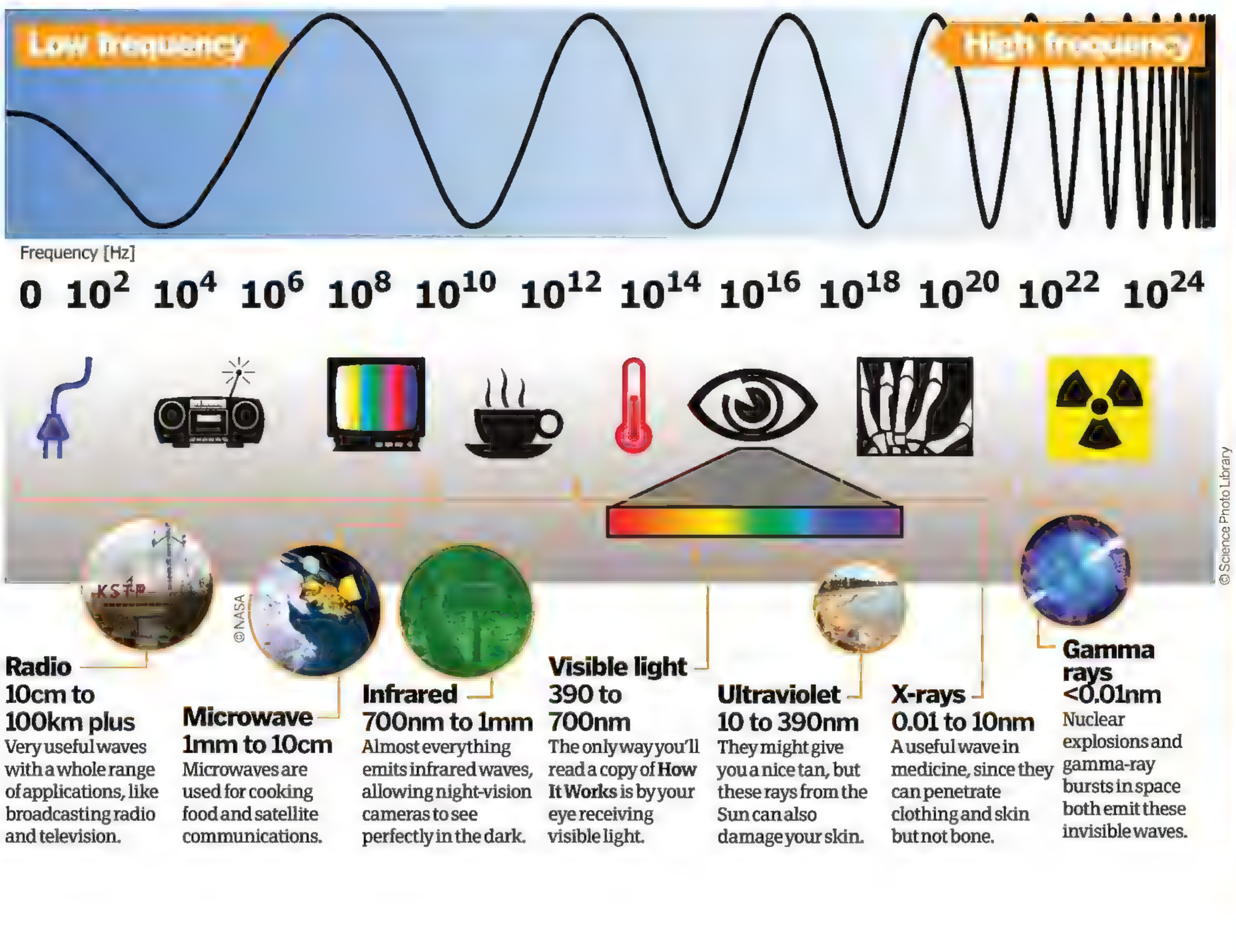


Colour blindness

[redacted]

The electromagnetic spectrum

Visible light makes up only a small portion of the spectrum. Have a look at where other electromagnetic waves feature



Radio
10cm to 100km plus
Very useful waves with a whole range of applications, like broadcasting radio and television.

Microwave
1mm to 10cm
Microwaves are used for cooking food and satellite communications.

Infrared
700nm to 1mm
Almost everything emits infrared waves, allowing night-vision cameras to see perfectly in the dark.

Visible light
390 to 700nm
The only way you'll read a copy of **How It Works** is by your eye receiving visible light.

Ultraviolet
10 to 390nm
They might give you a nice tan, but these rays from the Sun can also damage your skin.

X-rays
0.01 to 10nm
A useful wave in medicine, since they can penetrate clothing and skin but not bone.

Gamma rays
<0.01nm
Nuclear explosions and gamma-ray bursts in space both emit these invisible waves.

TECHNOLOGY

COULD WE BUILD JURASSIC PARK?

Words by Ailsa Harvey

As science advances, we may find bringing dinosaurs back to life is a realistic prospect

Welcome to Jurassic Park. As we open the gates to this zoo of previously extinct creatures, how would you expect the dinosaurs behind them to look? For those who have read or watched *Jurassic Park*, the image of a dinosaur may have already been planted in your mind. Your perception might be plagued by the gruesome scenes of park rangers becoming easy meals, or the film's iconic theme tune might resonate in your head as you envisage herds of long-necked beasts parading across the land. With great diversity between species, the thrill of this dinosaur park cannot be denied. But what about its accuracy?

When Michael Crichton first conceived the *Jurassic Park* story in the late 1980s, one of the last things he wrote was perhaps the most significant. How would the scientists in the story obtain the DNA needed to create a theme park of dinosaurs? This would be the key to the entire plot, giving the story a feeling of scientific realism. Eventually, Crichton was inspired by a scientific paper he read. The paper referenced a fly that had been found preserved inside hardened tree resin. Somehow, at the end of its life, the fly had ended up submerged in this resin time capsule. This was not just the stroke of genius that led to the creation of this fictional land, but a real-life discovery. Together the story of *Jurassic Park* and the science at the centre of the tale would inspire the next generation of palaeontologists, opening the world's imagination to dinosaurs.

What might fascinate people most about dinosaurs is the multitude of unanswered questions, with only hints at their dominance before our time. What did dinosaurs really look like, and how did their unique appendages assist them as they scoured the land in diverse groups?

As humans have never lived alongside dinosaurs, nobody holds the answers to some of the questions asked by children and adults alike. We continue to learn more about dinosaurs as interest and research grows – and with new fossil finds – and we have now discovered more than 700 dinosaur species worldwide, but as time passes by, it separates these ancient beasts further from us into the past.

Scientists are currently working to reverse extinction by bringing animals that vanished from Earth long ago back into our lives. By editing the genetic code in the DNA of extinct animals' closest living relatives, scientists can slowly build backwards and manipulate a model of the species' DNA. One of the most high-profile cases involves the woolly mammoth, which died out around 4,000 years ago. Their DNA is preserved in the frozen soil of Siberia, so some scientists are working on a project to combine these fragments of genetic code with that of living elephants. There might be thousands of years separating these species – and over 60 million years for dinosaurs – but if scientists are successful in producing these extinct species, this could be a stepping stone towards the beginning of a true Jurassic Park.

Have we found dinosaur DNA?

The biggest hurdle to overcome before we can create a dinosaur park is how to source the main ingredient. Without access to dinosaur DNA, we can't clone true dinosaurs. New fossils are being uncovered from the ground every day. However, while this can provide important evidence of a species' form, its organic material has long disappeared. Instead of bone is the rock and sediment that has filled its place. While these clues can tell us about a specimen's shape, size, the time it was alive and any unique features that the animal had, it is unable to give us the crucial genetic information.

In 2020, researchers from the US and China discovered cartilage that they believe to contain dinosaur DNA. Many palaeontologists are incredibly sceptical about this claim, as it is widely believed that it's impossible for the protein in these molecules to survive for millions of years. The cartilage, from the Hypacrosaurus species of the Cretaceous Period, is over 70 million years old, but has been calcified and fossilised, which may have protected the inside of the cells.

Bones can survive for millions of years, while soft tissue is the first to break down

CLONING DINOSAURS

Follow the method seen in *Jurassic Park* to extract dinosaur DNA and decipher the true science from the fiction

THE TRAPPED MOSQUITO

1

CELL SURVIVAL

2

MAKING A STRAND

3

THE FROG ADDITION

4

CREATING COPIES

5

Q&A JACK HORNER

Jurassic Park's scientific advisor has plans to make a pet dinosaur

© Alamy

Horner is the real palaeontologist who inspired the character of Dr Alan Grant in *Jurassic Park*. Since finding his first dinosaur bone at the age of eight, Horner has dug up the first dinosaur embryos, the first dinosaur eggs in the Western world and has discovered and named the dinosaur species 'Maiasaura'. During his time as the palaeontology consultant for the *Jurassic Park* films, Horner advised Steven Spielberg on how to make the portrayal of dinosaurs as realistic as possible. While he deems the cloning process pure fiction, this hasn't stopped Horner from trying to bring back the dinosaurs

How would a Jurassic Park need to be changed in real life?
If you really, seriously want to build a Jurassic Park and are not just making a movie, you want walls around the dinosaurs to keep them in. Reinforced concrete is going to work a lot better than electric fences, because electricity can go out. Electric fences were not a very good idea.

In reality, could any of the cloning processes seen in the film work?
We think we have found signals for DNA and that there might be tiny bits left, but not enough to use to make a dinosaur. We can get collagen and some dinosaur proteins, but not all the material we need. If we had the DNA, it would be ridiculous to put it in an ostrich egg. The thing to do would be to grow it in a test tube, because we have no idea how big the embryos of all dinosaurs are. Some dinosaur eggs are the size of ostrich eggs, but for a Tyrannosaur, we think they are a lot longer and they're bigger. It's like thinking about putting a human embryo inside a squirrel. If we're going to make a dinosaur, it's not going to be in the same way as *Jurassic Park*. That doesn't mean we can't make one. I actually have a laboratory where we are attempting to figure out how to make a dinosaur.

How are you trying to create a dinosaur?
It's called the dino-chicken project, and it's mostly based on genetic engineering. The idea is to use atavistic genes. They are basically ancestral genes, meaning that ancestral animals programmed certain features. For instance, occasionally children are born with extra vertebrae and form a low tail, which the doctor just picks off when the child is born. And every once in a while snakes are born with little appendages. Whales evolved from land animals, and occasionally they are born with extra limbs sticking out the side of themselves. These are atavistic genes. They were useful at one time, but through the course of evolution they have been turned off. Occasionally they are accidentally turned back on, and snakes get a set of legs.

I was hoping that some of the features of a dinosaur were atavistic in a bird. All bird species are related to one another, with one common ancestor – dinosaurs – so any bird should work. Chickens are the easiest thing to get eggs from, so I built a laboratory, hired some geneticists and developmental biologists and started seeing if we could find some of these potential atavistic genes.

© Alamy

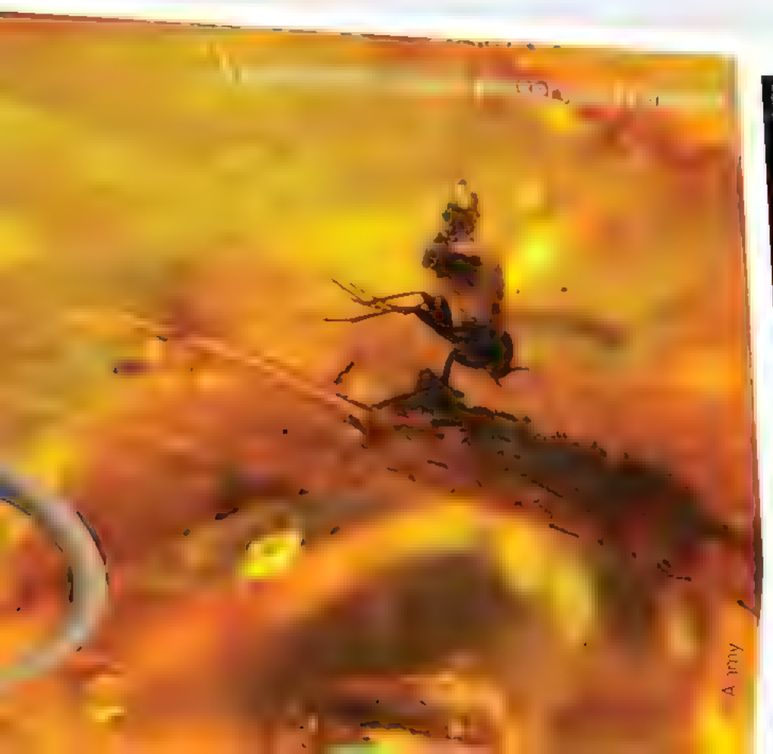
Tiny embryo in a test tube. A genetically engineered dinosaur would start like this

Why did you start this project?
I'd like to have a pet dinosaur. Wouldn't everybody like to have a pet dinosaur? I have a pet bird, but that's the closest I can get right now. When I started the project, everybody thought it was just crazy. But then, after a little while, other laboratories started working on it, like Yale University and McGill University, and they started finding some atavistic genes. We've been working on the tail, mostly, because that seems to be the hardest part.

"We are attempting to figure out how to make a dinosaur"

Is your method working?
We discovered that the reduction of the tail from long-tail dinosaur to a short-tail bird is not an atavistic gene. We are trying to figure out how the tail actually works and reverse the process that formed the short tail. Other laboratories have looked at the face, teeth, arms and hands. I think we can do pretty much all the rest of the body. We have the potential of making an animal that has a dinosaur-like head, probably with teeth in it, and we certainly have the capability of reversing the wings to make arms and hands. We know we can do that, but right now we're just trying to fix the tail.

If you succeed, would you make something similar to a Jurassic Park?
That's a whole different thing. People always say, 'where are you going to put these dinosaurs when you make them', and I always say that many thousands of years ago we started with wolves, and now we have Chihuahuas. Dogs are basically wolves, and we don't really have to contain them. I wouldn't expect dino-chickens to be the same as the dinosaurs in *Jurassic Park*. They're going to be domestic animals that we don't have to worry about. If you were cloning a real Tyrannosaur, you would have to worry about containing them. Dogs and cats were wild, but now we don't have to contain them – not to the point of making a park anyway.



© Alamy

Scientists cluster around a clutch of cloned dinosaur eggs in the Spielberg film

AR ZONE!

CREATING THE PARK

How would dinosaurs acclimatise to their new era and neighbours?

Tropical location
It's been determined that when dinosaurs roamed the Earth, the global temperature would have been around four degrees Celsius higher than it is today. An island in a tropical region of the globe would provide temperatures that many dinosaurs would be comfortable living in.

Substantial fences
Concrete or steel alone would be too weak to resist the power of a raging dinosaur. Reinforced concrete contains a lattice of steel inside to absorb the stress of any large impacts. It is also a versatile and fire-proof building material.

Electric control
Relying on electric fences for the entire park would be too risky to keep the dinosaur population under control. Any electricity shortage would result in large carnivorous dinosaurs being able to escape. They could be beneficial and safer to use for smaller plant-eating dinosaurs, however. This mechanism would work to deter the animals from crossing this line after they associate contact with the fence with the pain of an electric shock.

Herbivores
It's likely that many plant-eating dinosaurs would be able to live in the same enclosure in relative harmony. There is evidence of some species living in herds, and so fights between or within herds for better social positions might be observed.

AR ZONE! SCAN HERE

Living with dinosaurs

If dinosaurs hadn't gone extinct, humans are unlikely to have been able to evolve. During the 150 million years that dinosaurs existed, mammals lived alongside them, but these animals were nocturnal and lived in burrows. This suggests that this was the only way for mammals to thrive alongside dinosaurs, emerging mainly at night to hunt. Because our lives are completely separate to that of dinosaurs, there's no way of knowing what would happen if dinosaurs were to live on the same land as us.

By observing human behaviour with today's large predators, it seems unlikely that the two species would live naturally together. Humans take up so much space on the planet that introducing predators like dinosaurs outside of captivity would result in a battle for land.

Introducing meat-eating dinosaurs to Earth would give humans a natural predator

"With great diversity between species, the thrill of this park cannot be denied"

Smaller carnivores
The best way to ensure that the species brought into the park had the best chance of survival would be to separate the carnivores into groups that would have lived alongside each other during their reign. Without doing this, you would find that the evolutionary adaptations of some species no longer gave them an advantage.

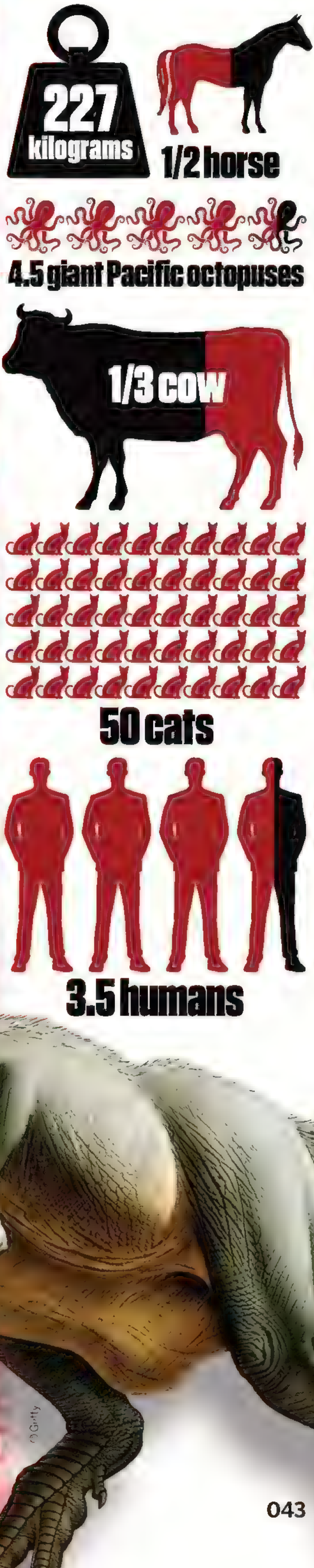
Plant variety
Most plant-eating dinosaurs are believed to have had flat teeth, ideal for tearing leaves off trees and grinding down plants. Tall, leafy plants would be needed for the long-necked herbivores, while shorter shrubs would benefit those relying on food closer to the ground.

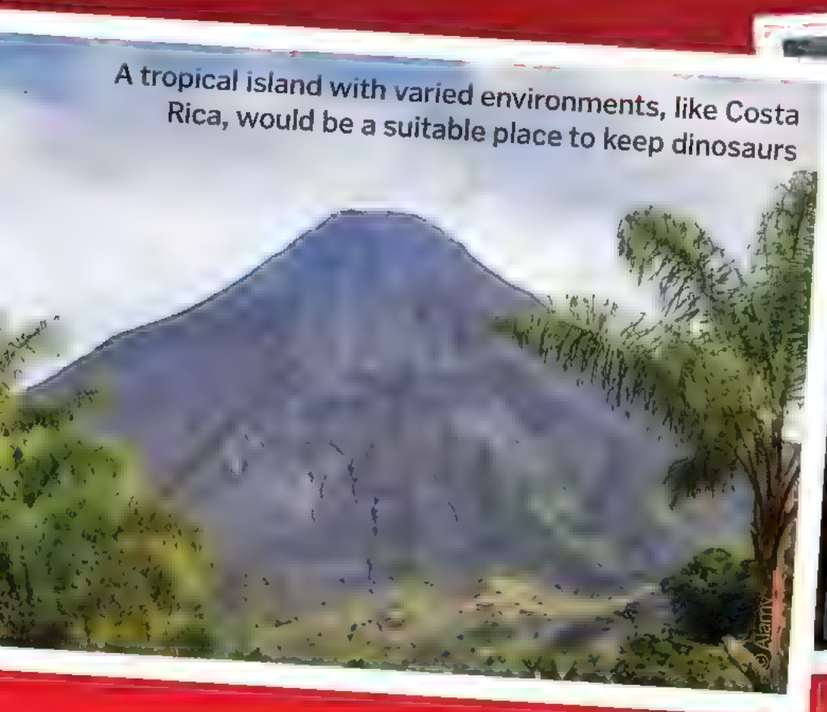
Large carnivores
For large carnivores such as the *Tyrannosaurus rex*, it would be important to provide them with significant space to roam and search for food. They should be kept in their own enclosure, as they could fight to the death if paired with similar-sized carnivores.

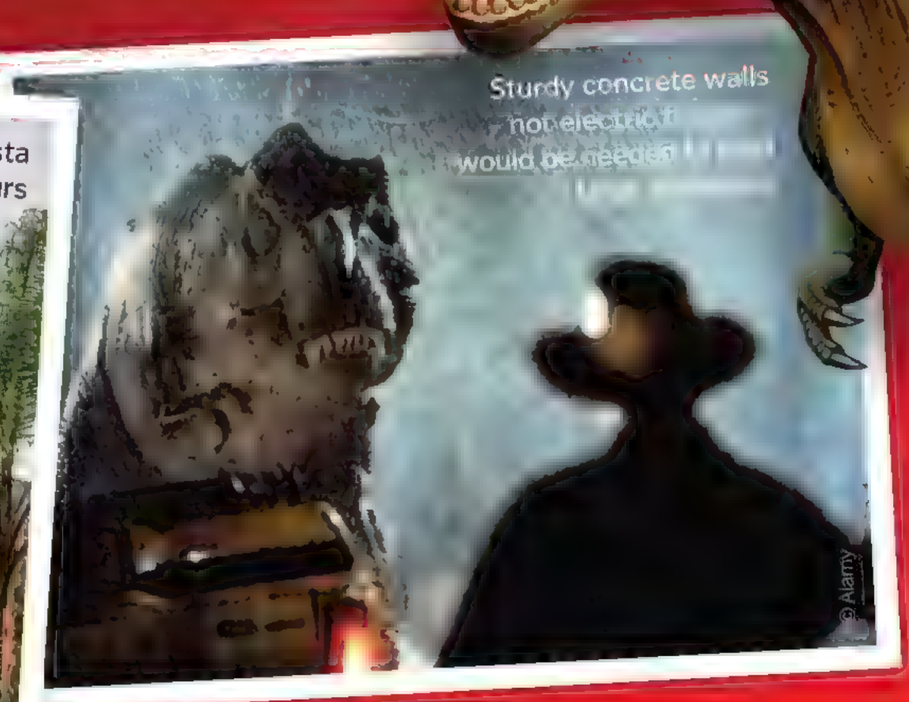
Aviary
With wingspans over seven metres, species such as the pteranodon could not be contained on an open island. In order to limit the movement of flying species, a large, dome-shaped enclosure would be needed.

Atmosphere adaption
Some studies of air trapped in amber show that its composition during the Cretaceous Period may have been 35 per cent oxygen, as opposed to today's 21 per cent. However, during the dinosaurs' extended time on the planet, this number is believed to have varied substantially. Some species would be better suited to our air than others.

A BITE TO EAT
How much food could an adult *T. rex* consume in one mouthful?




A tropical island with varied environments, like Costa Rica, would be a suitable place to keep dinosaurs



Achieving the liquid chocolate's smooth consistency is a lengthy process

How is chocolate made?

From the tree to your mouth, we reveal the secrets of the chocolate factory

© Getty

© Cadbury

© Cadbury

Chocolate production begins at the cocoa tree, where cocoa pods containing cocoa beans in a cotton wool-like pulp are harvested between the months of October and December. The beans are placed between layers of banana leaves for six days to drain the pulp away – a method known as 'heap' – before being dried in sunlight, packaged and sent to a factory for chocolate making.

Inside a chocolate factory the beans are heated inside a continuous roaster as they travel along a conveyor belt. The timing of this process varies depending on the flavour required. Once suitably roasted they are broken down into small pieces and their brittle shells are removed, leaving only their meaty centres, the 'nibs', which contain the cocoa butter essential for chocolate production. A mill grinds these nibs into a thick, brown liquid known as 'cocoa liquor', the basis of all chocolate products, which is then mixed with varying amounts of sugar and milk depending on the required type of chocolate. Typically dark chocolate consists of 70 per cent cocoa liquor, while milk and white chocolate have 30 per cent.

Vacuum ovens then dry this mixture into what is known as a chocolate 'crumb' before giant rollers squash the liquor together. It is then ground between rollers to improve the silky texture before being smoothed even further in a process known as 'conching'. This involves kneading the mixture in giant tanks heated to about 46 degrees Celsius, with the very best chocolate being conched for more than a week. The final process is tempering, where the liquid is continuously cooled and heated in a cycle until it is a stable chocolatey consistency.

After this final stage of the chocolate-making process the liquid can be poured into moulds, cooled and wrapped at high speeds to make products like bars of chocolate. To make chocolate with a particular filling, such as caramel, the insides of the bars pass along a conveyor belt and are 'enrobed' by the liquid chocolate before being cooled and wrapped.

© Cadbury

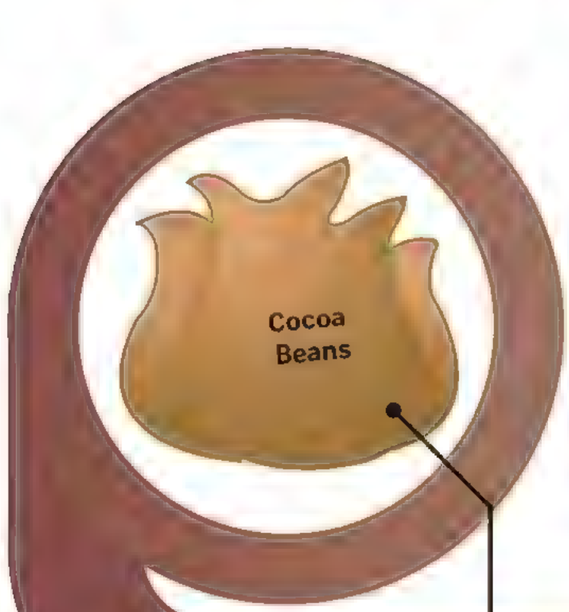
The custom of giving an egg at Easter has its origins in paganism

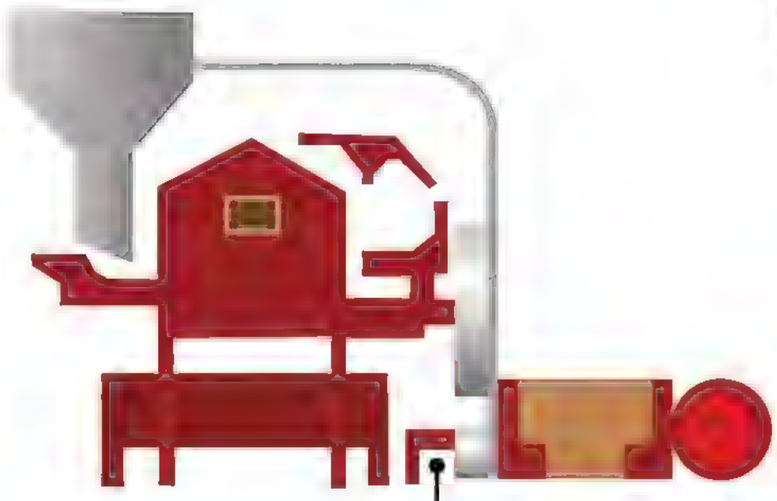
© Cadbury

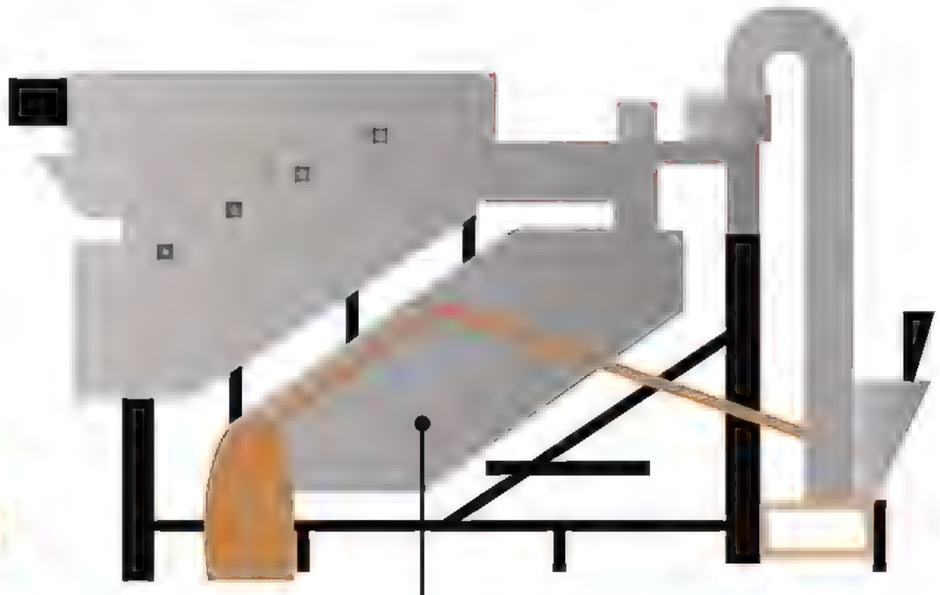
Giant tanks store liquid chocolate at 46°C

It's crafty at the chocolate factory

From bean to bar, how does chocolate make its way to your mouth?



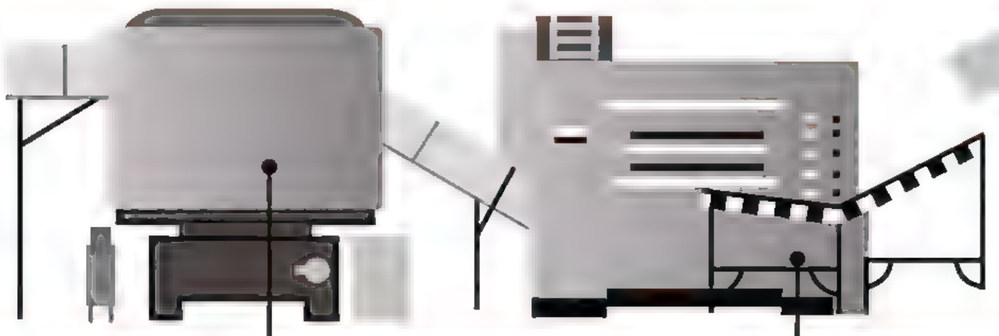


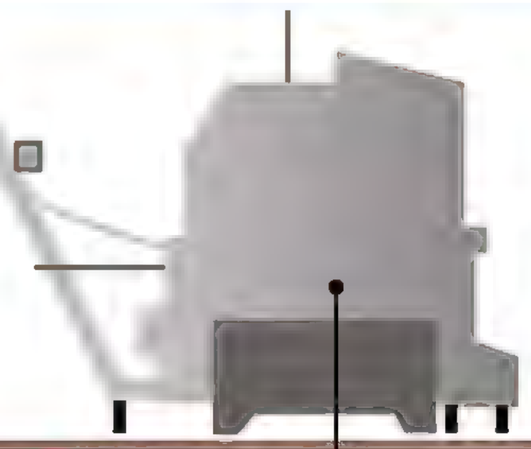


Harvesting
Cocoa beans are harvested in countries around

Roasting
To bring out flavour the cocoa beans are roasted,

Winnowing
This machine takes away the shell of the beans



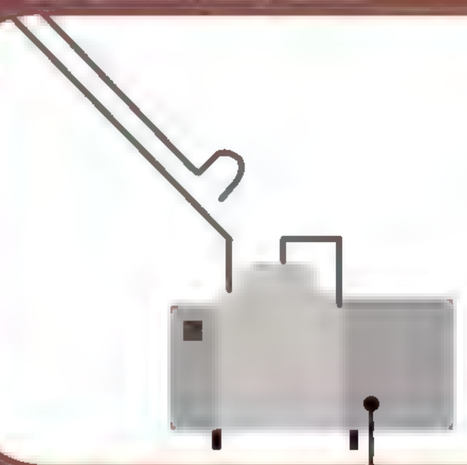


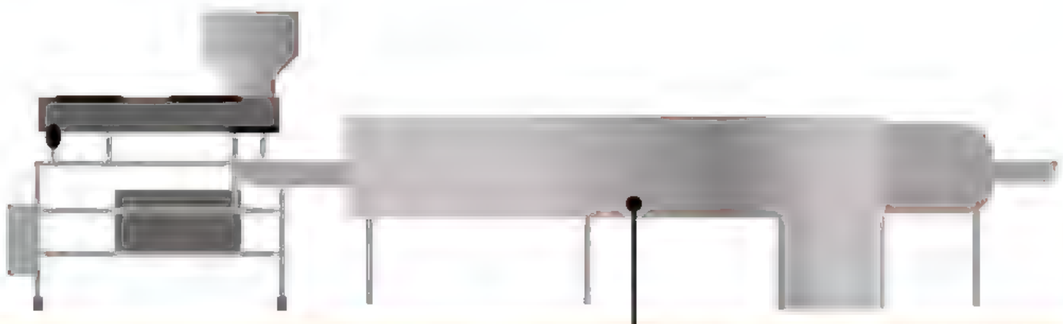
Conching
The paste is kneaded for up to seven

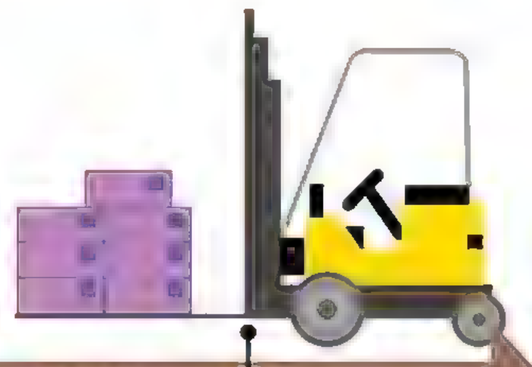
Refining
After flavourings have been added,

Pressing
Pressing produces a hard layoff that can

Milling
Nibs are ground into chocolate liquor, a







Tempering
The chocolate mixture is heated, cooled and reheated again, a process

Moulding
The chocolate paste can now be moulded into almost

Cooling
The chocolate is cooled,

ON THE MAP

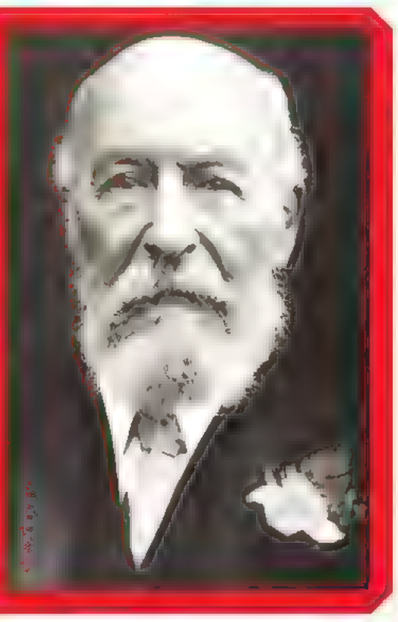
Top six cocoa bean growers

Only areas within 20 degrees of the equator can grow cocoa beans:

1 Ghana
2 Nigeria
3 Cameroon
4 Indonesia
5 Brazil
6 Ivory Coast

George Cadbury

In the 1830s John Cadbury started a small but not especially successful chocolate factory. Later his sons were to revitalise their father's failing empire. George built the factory town of Bournville – also the name of a dark chocolate Cadbury product – for its employees in the process.



BILLION HOME TECHNOLOGY

Words by **Ailsa Harvey**

Past the front doors of the world's wealthiest are the most extravagant pieces of home tech money can buy. If you've a spare billion in the bank, you might have one or two of these in your home...

LAIRES'

Visiting Bill Gates

When you have guests, you often want to go out of your way to keep them comfortable and entertained. You might stock up the fridge and tidy the house as a welcoming gesture. But for billionaires like Microsoft's founder Bill Gates, technology can do all the catering. When visitors arrive at his house, they can enter their temperature and lighting preferences into a device. They are then provided with a pin which tracks them as they navigate the different rooms. The house's sensors track their movement, and the internal climate adapts for them. There are also speakers placed in the walls, so if you want music playing while you're there, the sound can follow you as you walk through the mansion.

In terms of internal decoration, Gates' home is set to please the eye of any guest, as you can choose your own artwork. $80,000 (£58,000) worth of screens covering the walls allow guests to select any digital art or photograph and project it in an instant.

Bill Gates' home in Medina, Washington, is worth at least $127 million (£92.6 million)

Walker's improved coordination means the robot can pour drinks with no spillages

Go fetch

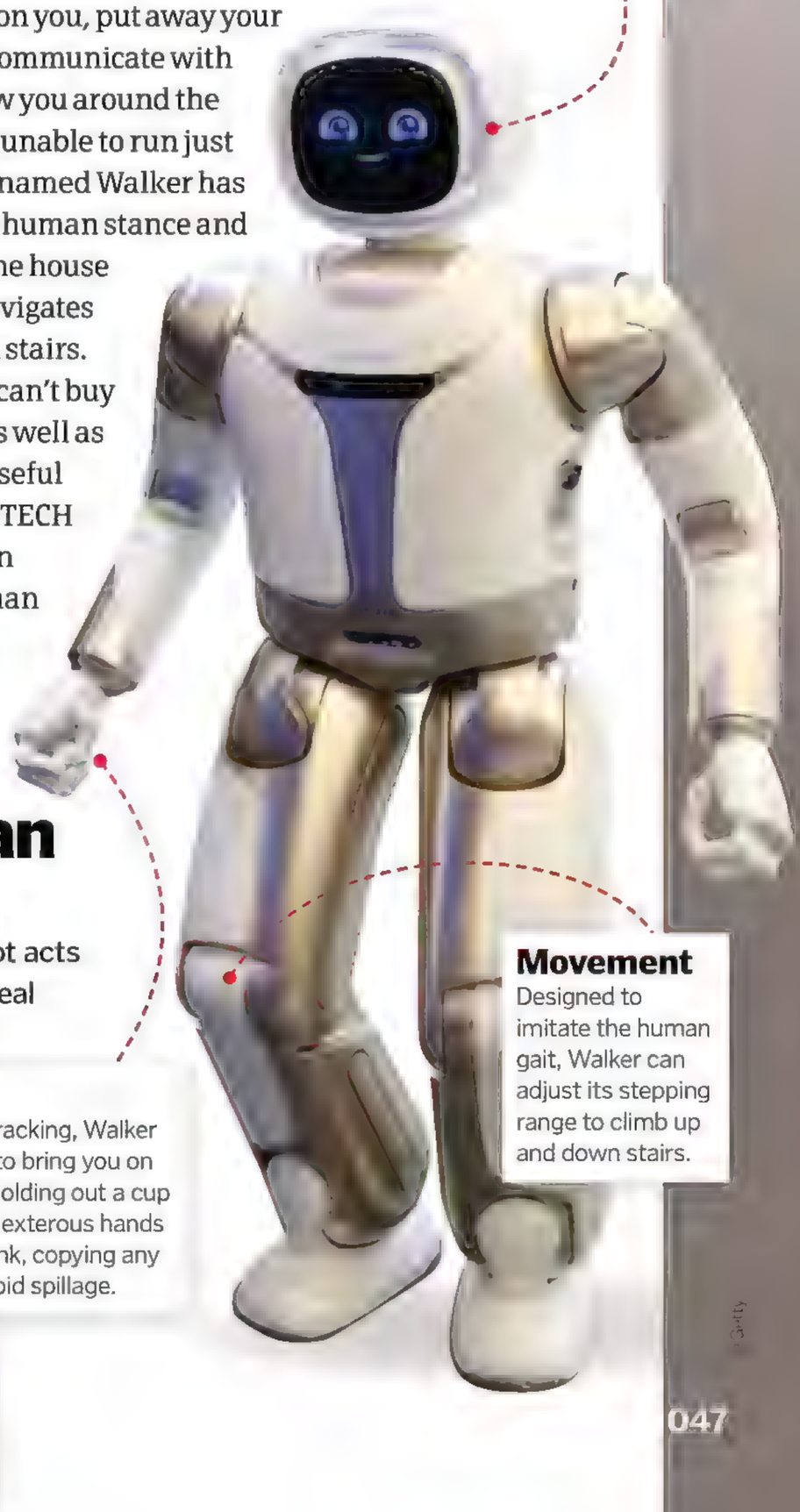
With advanced tracking, Walker can find objects to bring you on demand. When holding out a cup to the robot, its dexterous hands can refill your drink, copying any movement to avoid spillage.

WALKER THE ROBOT BUTLER

Long seen in futuristic films, the latest personal robots are bringing this idea into the real world. Walker is one of the most intelligent creations from UBTECH Robotics. Designed for the home, Walker can answer the door when the doorbell sounds, wait on you, put away your belongings, communicate with you and follow you around the house. While unable to run just yet, the aptly named Walker has mastered the human stance and remembers the house layout as it navigates the floors and stairs. They say you can't buy friends, but as well as performing useful functions, UBTECH has worked on Walker's human skills: it can dance, play and chat.

Memory

Acting like another member of the household, Walker remembers your name after you are initially introduced.



Human skills

How this robot acts like the real deal

Movement

Designed to imitate the human gait, Walker can adjust its stepping range to climb up and down stairs.

ULTIMATE SECURITY

How can the world's richest keep their luxury mansions safe?

It doesn't matter how lavish or humble our homes are, most people will feel concerned by the prospect of a robbery. Our houses are personal to us, containing our prized possessions, sentimental items and – in the case of some of the richest people – millions of pounds worth of technology.

As people gain money, they also gain attention. They are often at a higher risk of burglary, as well as darker crimes like kidnapping for ransom. However, owning the most desirable homes often means being able to afford some of the top security features. A turned key in the door isn't enough for the largest mansions. Any intruder daring to approach could face a 24-hour doorman guarding the entrance, instantly deployed shutters to close off the most valuable rooms and in some cases weapons. Remotely deployed fog blasts can be used to act as a visual barrier. If it doesn't scare the intruder away, it will stop them from seeing their way to valuable possessions.

Biometric iris scanners are estimated to be around ten-times more accurate than using fingerprints

Biometric entry
Instead of using physical keys, many of the world's richest use biometric scanners. Iris recognition is the fastest and most reliable, analysing unique patterns in the eye.

Bulletproof windows
Windows are often weak points for breaking and entering. But with large window panels creating a well-lit and stylish aesthetic, those who can afford it often opt for bulletproof glass. This provides them with their desired views without them becoming an easy target.

Escaping threats

What systems are available to detect intruders and protect billionaires from danger?

Infrared cameras
In most houses, it's impossible for your eyes to be on all rooms at once. But for those owning sizable mansions, checking every room simply takes too long. When your home is immense, there are areas you might not visit every day. Surveillance cameras act as essential extra eyes on your home, while infrared cameras are effective in locating the body heat of an intruder.

Escape route
Access points to the bunker can be designed to hide behind secret walls. When all members of the household are safely underground, the entrances are locked shut.

Biological wash
This may look like your average shower, but for a price of a few thousand pounds you can attach a biological washing system. In the event of a biological attack, toxic chemicals and biological agents can be washed away instantly from home.

AR ZONE! SCAN HERE

Rooftop heliport
In areas prone to natural disasters like fires and earthquakes, an efficient escape is essential. Installing a helipad on the roof of their homes, billionaires can be whisked away to avoid entrapment.

Footstep detector
Whether used at night or when the owner is residing in one of their other homes, detectors in the floorboards can alert them to suspicious activity within their mansions. Advanced systems use this data to estimate the number of people in the home, alerting the homeowner when numbers are above the usual.

Safe communication
Connected to surveillance cameras, movement above ground can be observed on screens. Microphones wired to the home's sound system can also allow those in the bunker to talk to intruders.

Luxury hideaway
For the super-rich, this bunker is more plush than most people's main living area. Equipped with around a week's food supply, it can become an underground home until the threat has passed.

Playground for the rich

Amazon founder Jeff Bezos entertainment facilities demonstrate how the richest relax

Golf simulation

For any golf fan wanting to improve on their game, an in-house simulator provides all-weather practise on virtual courses without needing to make a trip to the local golf course. For Jeff Bezos, this purchase was to accompany the real golf course that he already owns, which his mansion overlooks.

Simulators analyse your swing, while the screen records details of each shot

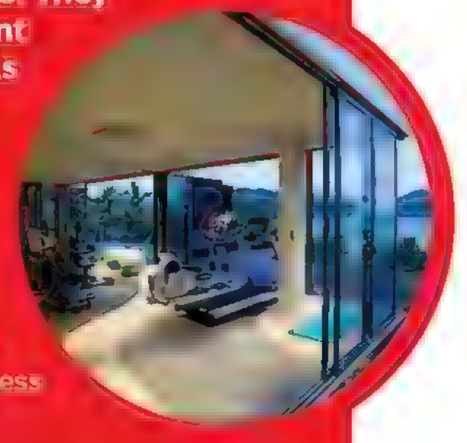
Personal cinemas

Who doesn't like to put their feet up and watch a new series, start a movie marathon or see what's on TV? People can spend many hours fixated on the box in the corner of the living room. But when money has no limits, what size TV do you get? A popular feature for many is a movie room. With their own personal cinemas, members of the family and any guests can often have a row to themselves as the screen fills an entire wall.

Bezos' house has a entertainment room with a home cinema

Indoor exercise

Gyms have become increasingly popular as people strive for healthier bodies and wish to look after their mental wellbeing. However, you won't find some of the richest individuals in these overcrowded facilities. They have all the equipment they need at home. As part of his personal gym, Jeff Bezos' Manhattan home comes with a yoga studio.



Smart-home gyms allow users to track their progress across equipment

KEEPING SUPERCARS

With the high prices of these cars, it's worth spending more to keep them secure

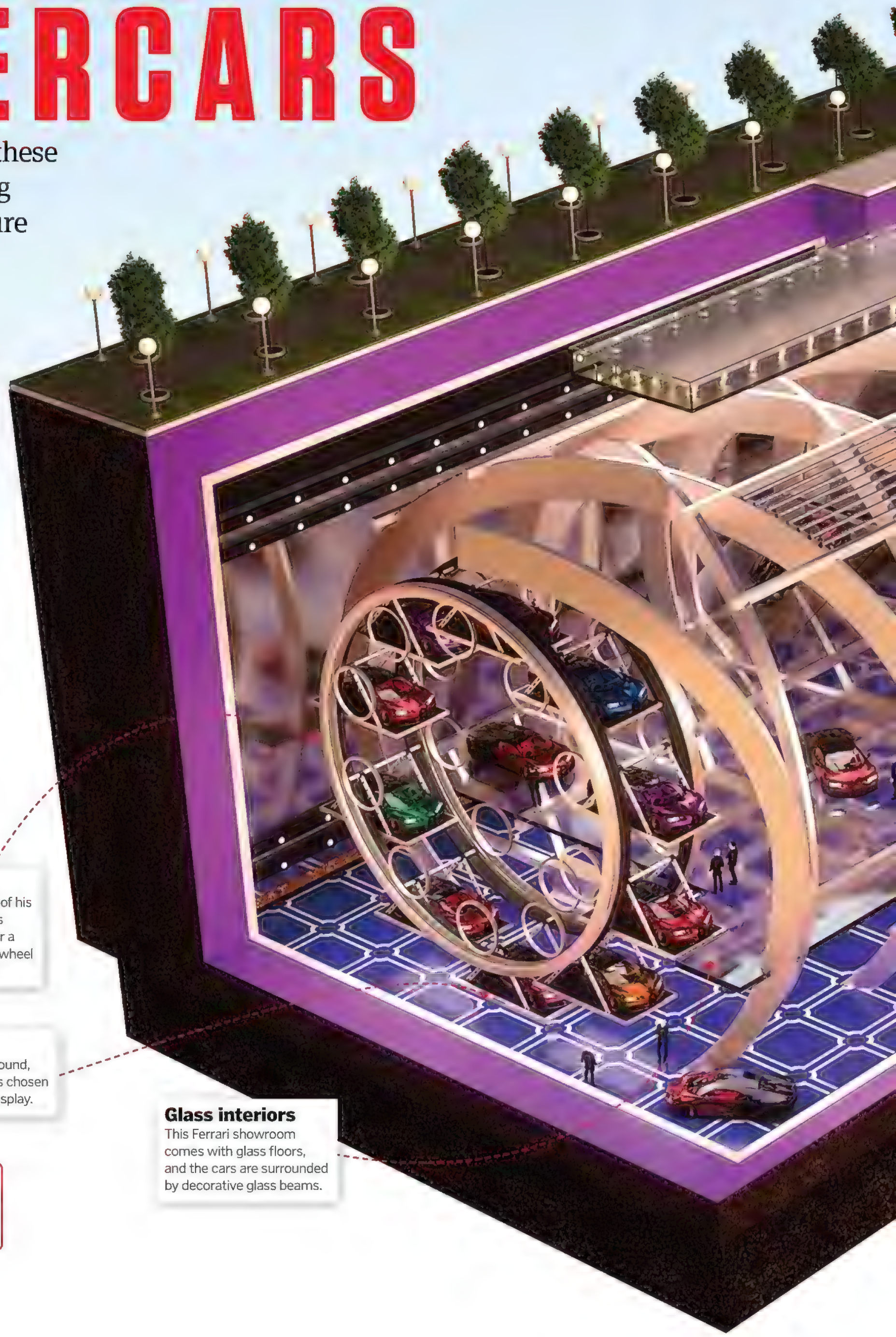
When you can afford the top cars on the market, the next question is where to store them. While some are content with one car, most of the super-rich enjoy a selection, putting them on display in extravagant home garages.

For Oprah Winfrey, who lives high in the mountains of Telluride, Colorado, the most regular threat to her drive is snow. For this reason she invested in a heated driveway to ensure her wheels are ready for a spin despite a night's snowstorm.

Some super-rich car lovers invest many millions into car storage, often giving their vehicles their own room in the house. As opposed to leaving their cars parked outside, car elevators have been invented to carry the car and its driver into the house's designated garage. This means speedy commutes for the driver, getting them onto the road without needing to step outside.

Car carousel

This underground garage was designed by British entrepreneur Jon Hunt to store his many Ferraris



Spinning wheel
Hunt has over 30 cars, but a few of his most prized hold positions on this carousel. When taking one out for a drive, the car is selected and the wheel spins to release it at the bottom.

Parking
Exiting the lift underground, the car is driven into its chosen position to rejoin the display.

Glass interiors
This Ferrari showroom comes with glass floors, and the cars are surrounded by decorative glass beams.

AR ZONE! SCAN HERE

Easy access
When returning home in the car of the day, the billionaire simply drives into a lift on the driveway, which carries the car below ground.

Underground extension
The design adds an extra five-storey chamber underneath the home.

Sizable museum
The entire basement is 24 metres in height, creating a spacious car museum.

Parking space
At 55 metres in length, the garage is about half as long as a football pitch.

5 FACTS ABOUT EXPENSIVE LUXURIES FOR EACH ROOM

1 Bedroom
Dutch architect Janjaap Ruijssenaars has designed a £1.2 million ($1.65 million) floating bed. The design uses strong magnets to keep the user hovering above the ground all night.

2 Bathroom
A bathtub was sold for £1.5 million ($2 million) because it was made of 180-million-year-old petrified wood. Designer Nigel Fenwick discovered the wood while exploring an Indonesian rainforest.

3 Living room
The 370-inch Titan Zeus is the largest TV screen you can buy. Costing £1.17 million ($1.6 million), the screen is made for both indoor and outdoor use.

4 Kitchen
Instead of simply storing and cooling food, smart fridges can analyse the food inside, alerting you to which foods you're running out of and which are going off.

5 Garden
Finding the time to tend to the plants in your garden can be difficult, so why not have a computer monitor each plant? That's what Bill Gates did to his favourite maple tree. When it gets dry, water is pumped to the roots.

Jarvis: meet Mark Zuckerberg's assistant

When the creator of Facebook sought the help of artificial intelligence to assist him in his home, he was looking for something personal. Instead of installing commercially available software, Zuckerberg designed his own. Inspired by *Iron Man*, 'Jarvis' connects to his household appliances, including his cameras, speakers, lights and toaster. Now Zuckerberg doesn't even need to make his own toast, as text and voice-operated Jarvis can do that for him. With voice recognition, Jarvis can detect who is asking, and even plays different music based on the known preferences of the person who asked.

Instead of running around his home to find his family members, Zuckerberg can just ask Jarvis where his wife and kids are. Using a similar system to Facebook's own face recognition, the assistant can locate known faces around the house or tell him who is at his front door by connecting to the door's camera.

Zuckerberg prefers to control Jarvis with his phone than with voice commands

RECYCLING

What kind of machinery do we use to take our everyday waste and make new products out of it?

Take a look around you. Practically everything that you see which is human-made can be recycled. Everything from this bookazine you're holding, the wooden table you're sitting at, the fabric of the clothes you're wearing, the battery in your mobile phone, the components of your computer and even the materials that make up the building around you... But not everything is recycled – why is that?

What can and can't be recycled is quite an expansive question, but for domestic purposes, it depends very much on the recycling facilities available to your local authorities. Materials like paper and plastics – as long as they aren't too contaminated – can be processed and baled into a raw material ready for reuse. Metals – especially more valuable ones like lead, copper and aluminium – are highly sought after. All these materials have unique recycling processes that have been an established part of manufacturing for over a century, with scrap metal merchants and salvage yards forming a significant industry all of their own.

Many scrap electronics can be stripped down to make new products too. Car parts can be salvaged and gold can even be extracted from computer chips. For some materials, such as mercury, heavy metals like lithium and electrolytes in batteries, recycling might not make financial sense, but because of their toxic nature, recycling them is a legal requirement.

In this feature, we check out the specialised machinery and processes that take our daily refuse and turn it back into products that we can use again and again.

"Aluminium and copper are recovered with a magnetic field that repulses non-ferrous metals"

Aluminium recycling

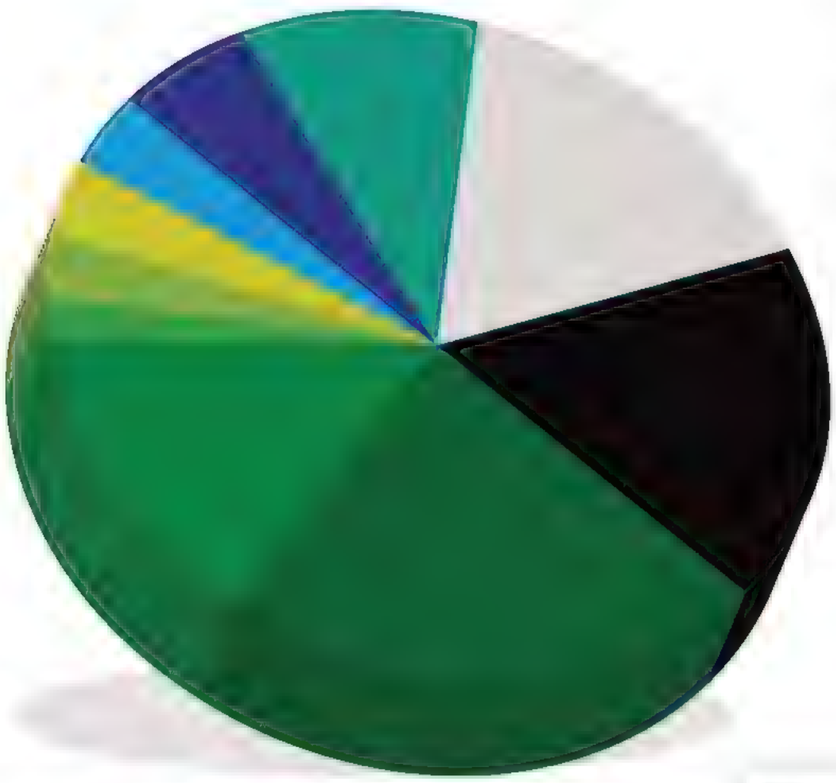
Aluminium in particular is highly sought after as a scrap metal. Because it is both lightweight and strong, it's used everywhere from drinks cans to aeroplanes. Extracting aluminium from its ore, bauxite, is relatively expensive, but salvaging it from scrap uses just five per cent of the energy needed to make new aluminium.

Like plastic bottles, a large percentage of recycled aluminium comes from beverage containers. The process is similar to plastics too. Once collected, they're separated from the other metals by an eddy current separator that splits the non-ferrous aluminium with a powerful magnet. The aluminium is shredded into pieces of uniform size, mechanically cleaned and then pressed into blocks to minimise oxidation. The blocks are loaded into a furnace and heated to around 750 degrees Celsius, at which point it becomes molten. The melted-down aluminium produces a surface scum known in the industry as dross, which is removed before high-purity aluminium is added to bring the molten aluminium up to the required grade. The furnace is then rolled onto its side and the liquid aluminium poured out. The end product is either atomised aluminium powder or ingots. Because aluminium isn't transmuted by this process, it's just as good as the new stuff and can be recycled indefinitely.

Once old aluminium has been processed, it can be melted down to make new products time and again

UK refuse breakdown

HIW reveals the various materials which make up annual household waste in Britain

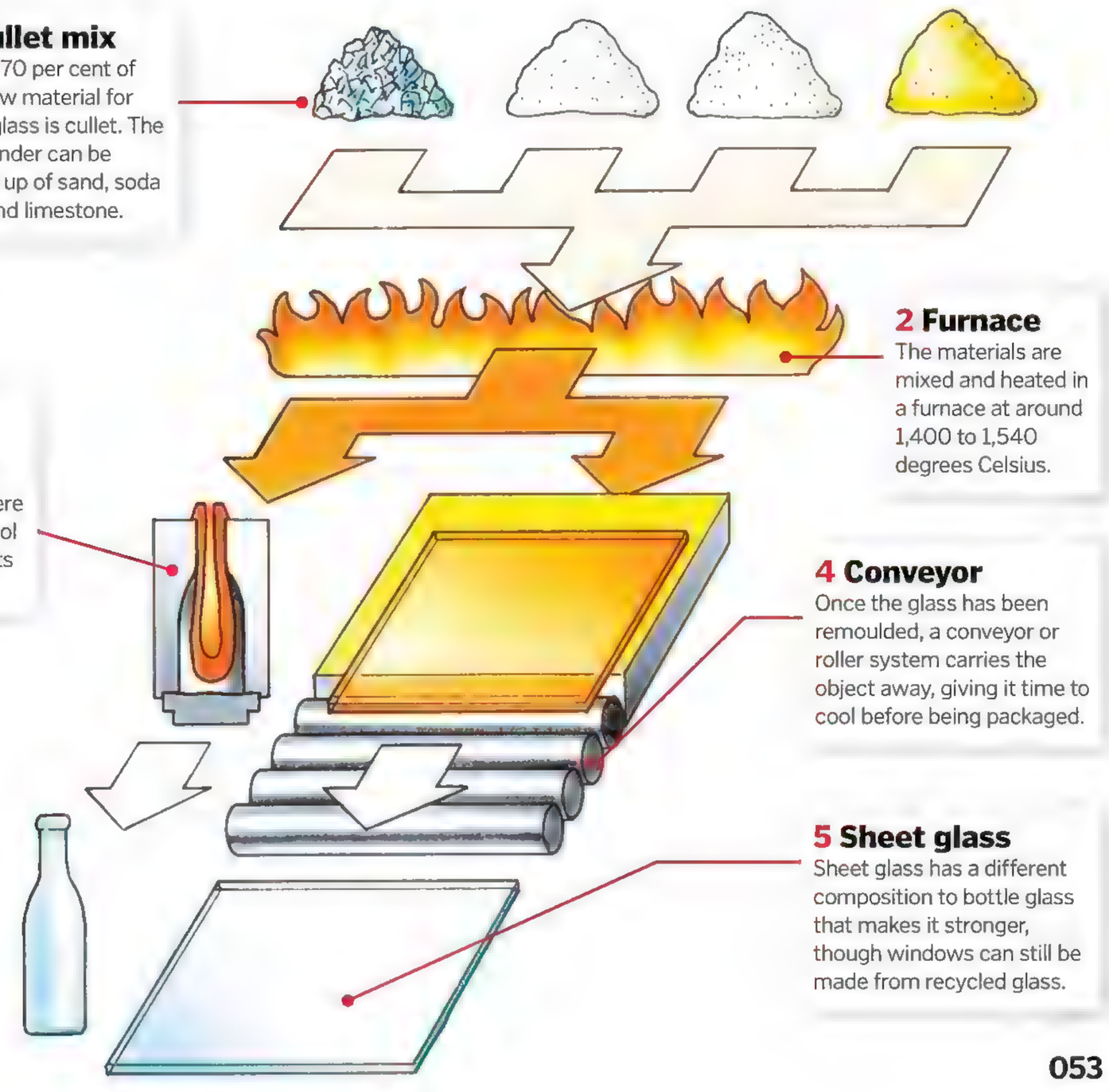


- Waste electricals: **2%**
- Textiles: **3%**
- Wood: **4%**
- Metals: **4%**
- Glass: **6%**
- Plastics: **10%**
- Garden and organics: **16%**
- Food: **18%**
- Paper and card: **23%**
- Other: **14%**

Source Defra (2006-7)

Glass recycling

Glass recycling is an old industry that has evolved over decades. A large proportion of glass still makes up household and industrial waste, most of it bottles and glassware. Glass from bottle banks and household recycling is collected and taken to a cullet processing plant. Manual sorting separates metal and plastic contaminants as well as the various glass colours: chemicals used for different coloured glass can't be removed. The glass is washed and often passed through a ferrous metal removal machine to capture any metal contaminants that could damage machinery and taint the quality of the final product. The glass is next passed through a belt crusher that pulverises it to a uniform grade. The material is now known as cullet and is ready to be made into new products.



1 Cullet mix
Up to 70 per cent of the raw material for new glass is cullet. The remainder can be made up of sand, soda ash and limestone.

2 Furnace
The materials are mixed and heated in a furnace at around 1,400 to 1,540 degrees Celsius.

3 Mould
Melt glass for bottles is poured into a mould, where it is allowed to cool and solidify into its new form.

4 Conveyor
Once the glass has been remoulded, a conveyor or roller system carries the object away, giving it time to cool before being packaged.

5 Sheet glass
Sheet glass has a different composition to bottle glass that makes it stronger, though windows can still be made from recycled glass.

SORT IT OUT!

How are recyclables mechanically sorted? The EcoTowerSort separation system divides the rubbish from the good stuff

1 Vacuum
The first stage of separation uses a vacuum to suck fluff and light waste away from the bulk of the rubbish.

2 Ferrous separation
A powerful magnet in the second stage picks up ferrous metals – containing high quantities of iron – and drops them into a hopper.

3 Eddy current separator
Aluminium and copper are recovered with a magnetic field that repulses non-ferrous metals, ejecting them down a collection chute.

4 Sensor separator
The fourth stage uses a high-precision magnetic separator to pick out stainless steel.

Rubbish collection
- Fluff
- Dust

Stainless steel collection
- Kitchenware
- Scrap electronic parts
- Nails

Ferrous collection
- Containers
- Food cans
- Construction materials

5 Fine separation
For the fifth and final stage a high-sensitivity magnetic separation system picks out any tiny pieces of non-ferrous metal, like wire, that may still be in the waste.

Rubbish collection

Wire and fine metal collection
- Scrap electronics
- New cables/wires

Key:
- Aluminium
- Wire and fine metal
- Rubbish
- Stainless steel
- Ferrous (iron-rich)

What happens to my drinks bottle?

Take a look at the two potential life cycles of a plastic bottle

A bottle
Some drinks bottles are recyclable, but others aren't – often because they have already been recycled once. Recyclable plastic usually has a recognisable symbol.

Recyclable waste
We use around 20-times more plastic than we did 50 years ago. Currently about a third of the plastic bottles we bin are recycled.

Collection
The local council collects your rubbish. In some areas, recyclables are separated on the lorry during collection, while in others they are placed together and sorted at a later stage.

Sorting
A reclamation yard, or materials recovery facility (MRF), will sort the plastics from other recyclable materials.

Bale sale
Balers squash plastic bottles and turn them into cubes that can be sold to reprocessing plants.

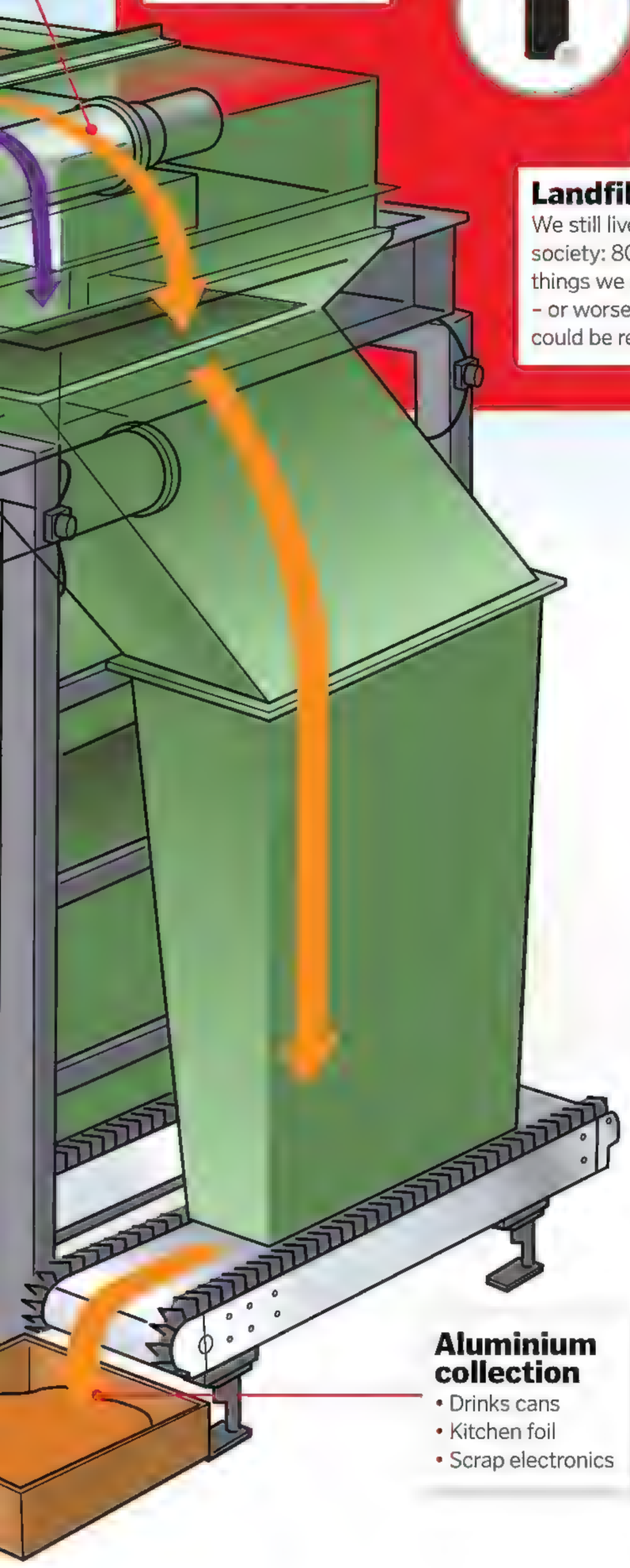
General waste
Depending on the country, up to two-thirds of all plastic bottles don't go to the recycling plant.

Reprocessing
The reprocessing plants sort the plastics according to the various types. It then washes and chips the plastic into flakes or pellets.

Landfill
We still live in a disposable society: 80 per cent of the things we send to landfill – or worse, the ocean – could be recycled.

Decomposition
Newer, biodegradable plastics can break down within a few years, but most plastic takes around 450 years to decompose.

New products
The recycled plastic is heated and remoulded in order to make new products, like clothing.



Aluminium collection
- Drinks cans
- Kitchen foil
- Scrap electronics

Recycling in numbers

40KG
Plastic wasted by a family annually

£36m
Cost of aluminium thrown away per year

50%
The amount of glass that is recycled in the UK

250 million
trees saved if all US newspapers were recycled

24
trees to make one tonne of paper

25
recycled PET bottles can be used to make an adult's fleece jacket

500 years
How long it takes for a nappy to decompose

Record players

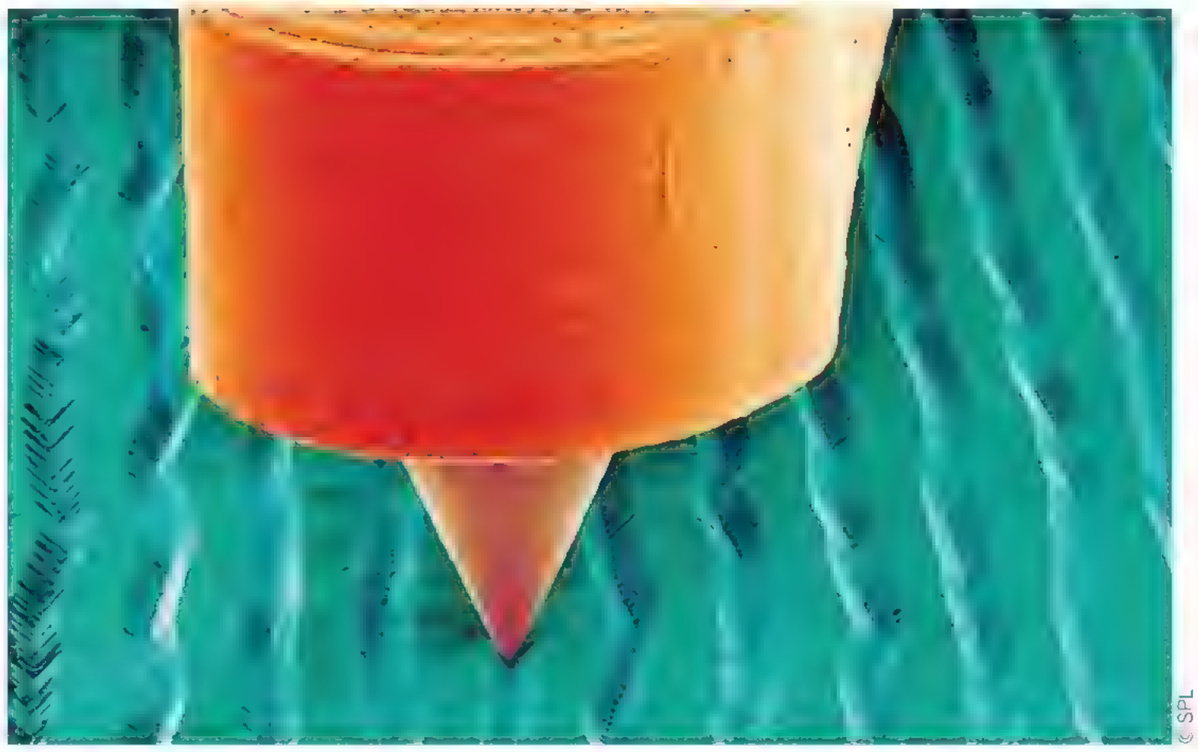
How sound is recorded and replayed from vinyl

Vinyl records are the audio storage media of yesteryear – though they are having a re-emergence in popularity. You can think of them as MP3 players that simply store sound using a different system: older hard-disk drives use magnetism to store this information, reading and writing using an arm that sweeps back and forth across spinning magnetic plates. Flash-memory music players like iPods, meanwhile, make use of transistor technology to store digital music, while compact discs have tiny pits pressed into the silver layer by a laser, which can be read by a CD player.

Records work in a very similar – if more tangible – way to the latest playback devices, though the same principles behind 19th-century phonographs can be seen at work in modern turntables. The tiny grooves in the record vibrate a crystal in the stylus, or needle, at the end of the arm as it moves across the record's surface. The resulting microscopic jolts move a metal bar that squeezes a piezoelectric crystal, generating an electric signal. The signal is fed to the amplifier that interprets it, then sends it out to the speakers which replicate the original sound.

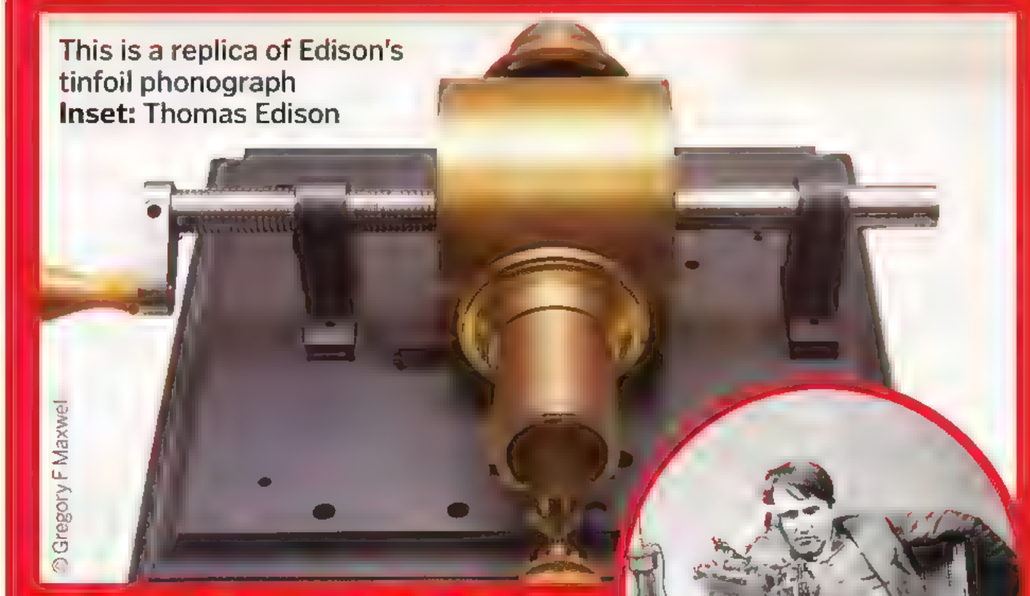
Today's records are made of vinyl, pressed from a metal 'mother' that is cut using highly specialised machines. But even though the recording is of a much higher quality, you can still spin the turntable by hand to hear the record play without any intervention from modern technology.

A shot taken by a scanning electron microscope of a stylus running along a groove in a record



© SPL

This is a replica of Edison's tinfoil phonograph
Inset: Thomas Edison



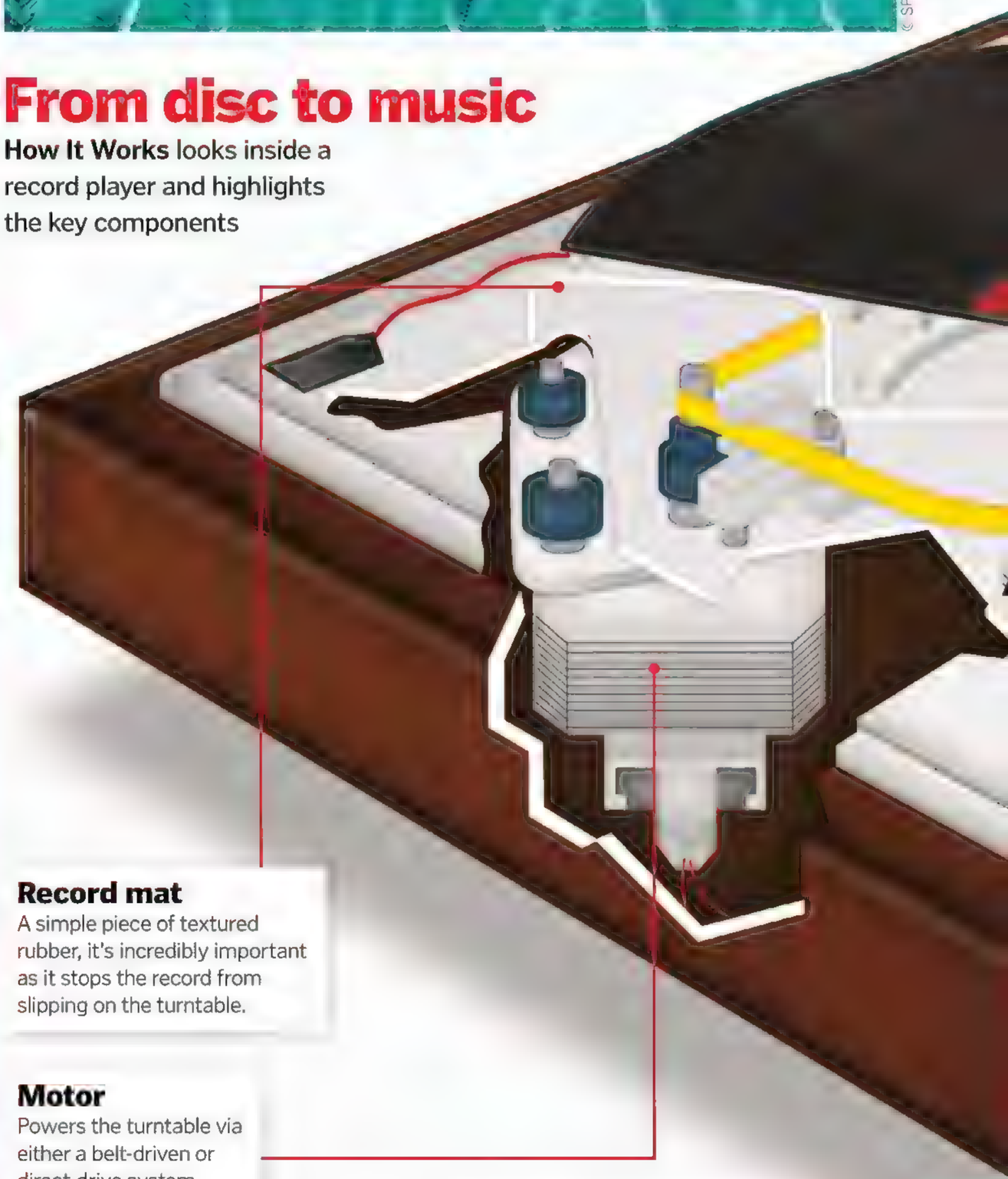
© Gregory F Maxwel

Birth of the gramophone

In 1877, over a century before the dawn of digital music recording, Thomas Edison discovered that by attaching a needle to the diaphragm of a telephone receiver, a visual representation of the sound could be drawn when the needle vibrated along a cylinder covered in tinfoil. By attaching a horn and rotating the cylinder by hand, the sound could then be reproduced. Edison put his work on the phonograph on hiatus while he focused on electricity. In the meantime, Emile Berliner stepped in to create a more practical machine that used flat black discs, but could only play and not record. This was the gramophone, and its records could be mass-produced via Berliner's Gramophone Company. The basic format for sound recording remained the same up until the 1980s, when cassette tapes became standard.

From disc to music

How It Works looks inside a record player and highlights the key components



Record mat
A simple piece of textured rubber, it's incredibly important as it stops the record from slipping on the turntable.

Motor
Powers the turntable via either a belt-driven or direct-drive system.

Stylus
Tipped with a tiny diamond or hard mineral, the needle moves within the grooves on a record.

Cartridge
This is a plastic housing for the stylus that converts the vibrations from the contact with the record into electrical signals.

How we consume music has changed radically over the last century

Record
The record is pressed from a 'biscuit' of vinyl, though they were first made of shellac, the resin from the scaly lac bug.

Tonearm
This mechanical arm, also known as the pickup, glides across the record with the stylus and delivers the electrical signals into the amplifier.

Servo
This highly engineered box of tricks controls stylus pressure and helps prevent the arm from skating across the vinyl disc.

Turntable
Modern turntables keep the record spinning at a constant rate for both 30-centimetre and 18-centimetre records.

Suspension
A series of springs positioned beneath the turntable designed to provide stability to ensure smooth and accurate audio.

Disc-size selector
This needs to be specially set to accommodate the diameter of a record and is connected to the auto/manual operating lever.

Cabinet
The outer casing which houses the record-playing machinery is often made of top-quality wood, primarily for aesthetic purposes.

World's most famous record

Probably the most recognised record in the world – and beyond – is the Golden Record that was placed aboard the Voyager 1 and 2 spacecraft. They are two 30-centimetre copper phonographs plated with gold, and on them are recorded sounds, music and greetings from Earth in 55 languages, including Beethoven's *Fifth Symphony*, "Hello from the children of planet Earth" in English and the sound of crickets and frogs. They're encased in aluminium jackets and include a needle and cartridge along with instructions for any intelligent extraterrestrial life that happens upon Voyager on how to play the records. The records are designed to be played at 16⅔ revolutions per minute – half the speed of the 33⅓ standard for a commercial 30-centimetre vinyl. Since its launch in 1977, Voyager 1 has travelled over 22 billion kilometres, making the Golden Record one of the few humanmade objects to have left the Solar System.

How dental drills work

What makes this precision tool perfect for many different dental jobs?

High-speed drills are used for excavating hard enamel, while low-speed devices are better for polishing and finishing enamel

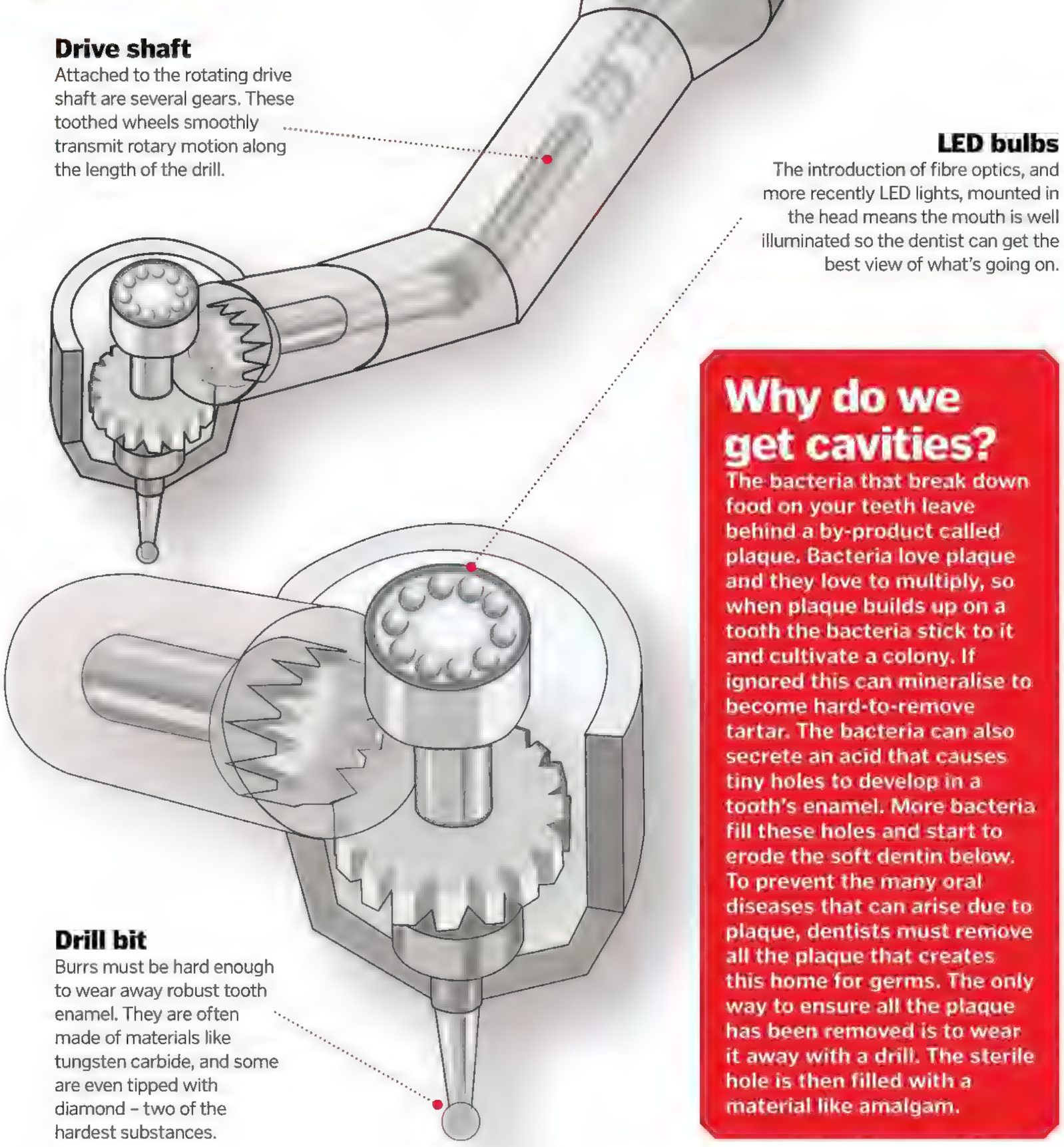
Powered by electric or air-driven motors, modern dental drills have come a long way since the early days of medieval dentistry. As well as a motor, the other main components of today's dental drills are an ergonomic handpiece, gears and a tungsten drill bit, also known as a burr. Located inside the drill's handpiece is a series of drive shafts and gears that transmit rotary motion from the power supply to the tungsten drill bit at the head end.

Electrically motorised drills can rotate at about 30,000 rotations per minute. For a turbine-powered drill, a compressor converts pressurised air into mechanical energy that rotates the burr at over 300,000 rotations per minute. This generates a huge amount of heat, so high-speed devices are also connected to a cooling water supply.

New technologies in development – including laser and air-abrasion drills – are hoping to improve the experience of going to the dentist by providing drills that remove decay without generating the heat, noise and vibrations associated with their predecessors. The laser drill achieves this by combining the high-speed pulsed light from a laser with an atomised spray of water droplets to generate hydrokinetic energy. Air-abrasion drills, meanwhile, work like a mini sandblaster, firing a stream of abrasive powder, such as silica or ammonium oxide, at the tooth to blast the decay away.

Getting to know the drill

What are the main elements that make up this high-speed tool of the dentist's trade?



Turbine type
The rotary system in an air-powered turbine drill features an impeller (rotor) to catch air from the compressor. The rotor is mounted on a spindle that rotates at high speed.

Handpiece
The motor, gears and drive shaft are contained within the handpiece, which can be made of either plastic or titanium.

Drive shaft
Attached to the rotating drive shaft are several gears. These toothed wheels smoothly transmit rotary motion along the length of the drill.

LED bulbs
The introduction of fibre optics, and more recently LED lights, mounted in the head means the mouth is well illuminated so the dentist can get the best view of what's going on.

Drill bit
Burrs must be hard enough to wear away robust tooth enamel. They are often made of materials like tungsten carbide, and some are even tipped with diamond – two of the hardest substances.

Why do we get cavities?

The bacteria that break down food on your teeth leave behind a by-product called plaque. Bacteria love plaque and they love to multiply, so when plaque builds up on a tooth the bacteria stick to it and cultivate a colony. If ignored this can mineralise to become hard-to-remove tartar. The bacteria can also secrete an acid that causes tiny holes to develop in a tooth's enamel. More bacteria fill these holes and start to erode the soft dentin below. To prevent the many oral diseases that can arise due to plaque, dentists must remove all the plaque that creates this home for germs. The only way to ensure all the plaque has been removed is to wear it away with a drill. The sterile hole is then filled with a material like amalgam.

Wave power

Generating electricity using the motion of the ocean

Words by **Ailsa Harvey**

Finding renewable energy sources has become more essential than ever as scientists seek solutions to the climate crisis and better ways to supply our expanding energy needs. Two of the most popular natural resources used to generate electricity are the Sun and wind. However, energy from the ocean is a more consistent source.

Water covers more than two-thirds of our planet's surface, and its natural motion is unceasing. While solar power is limited to daylight hours and wind power is dictated by the weather, wave power remains constant. The strength and frequency of waves can vary, but the sea is never totally still.

But how is it possible to create electricity from this motion? The energy-converting devices responsible vary in their design. Some are relatively small, but float on the surface of the ocean in large numbers. As these move with the fluctuations of the water in wavy conditions, the energy creating this movement is harnessed using magnets.

Other devices have a flat panel design that can be fully immersed in the water. With a large surface area, these devices move with the direction of the waves like a pendulum, tilting one way then the other. One crucial component inside these devices is the hydraulic ram, which pumps high-pressure fluid through the hydraulic motors. The movement of the hydraulic motors causes the electrical generators to produce an electric current.

This wave-energy buoy was placed off the coast of Kane'ohe Bay in Hawaii to provide energy for Honolulu

© Alamy

The world's largest wave farm

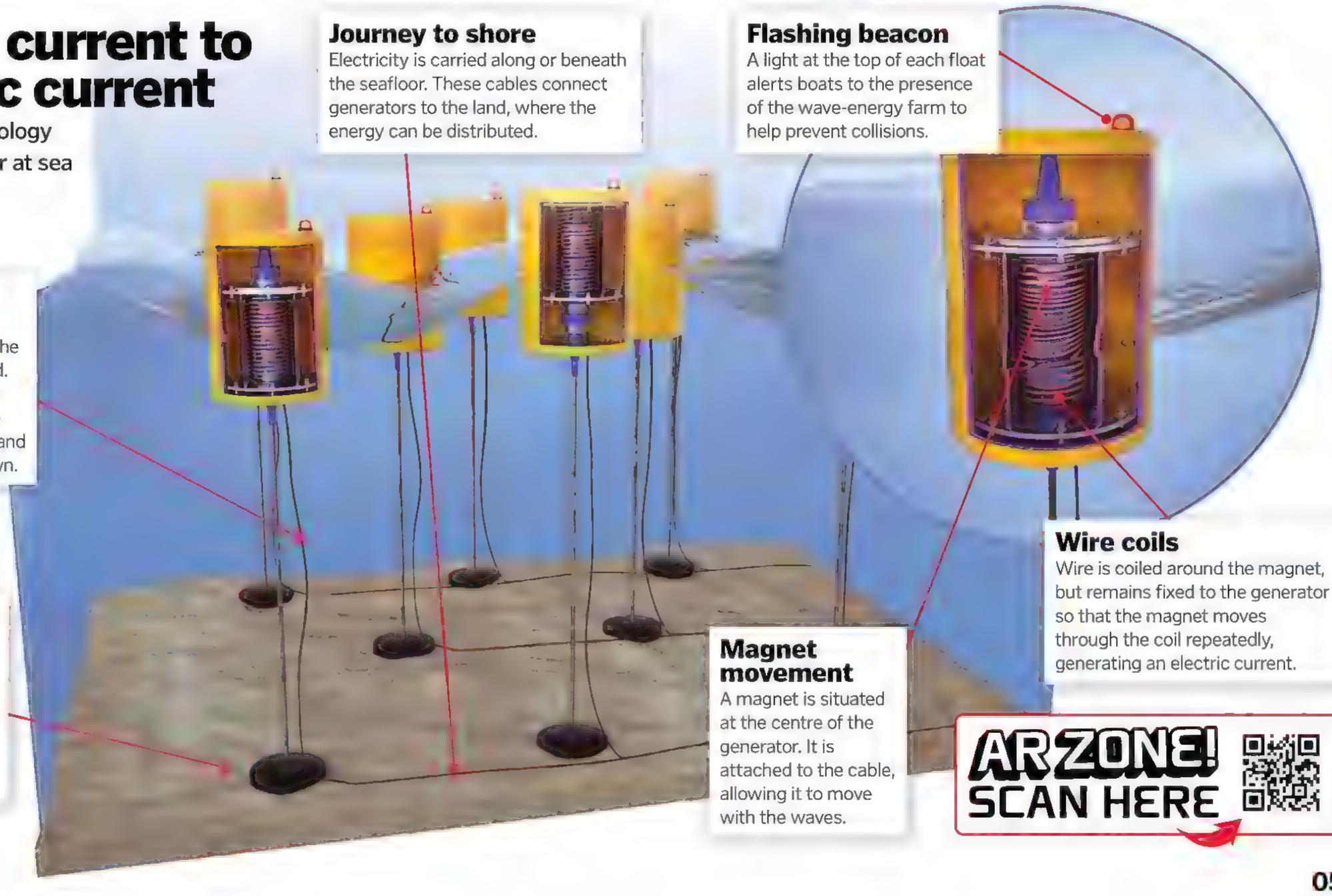
Aquamarine Power is a Scottish marine engineering company set to build the world's largest wave energy farm. Having been approved by the Scottish Government, as well as the local council, the site is due to be installed off the Isle of Lewis and has the potential to power around 30,000 homes when complete.

The company aims to set up between 40 and 50 of its energy-producing devices. Called Oyster, these will be bolted to the seafloor. Provided it's installed in water at least 10 to 12 metres deep, Oyster generates electricity through the movement of a vertically standing panel. As the waves move horizontally, panels are pushed, causing them to flap backwards and forwards. This is the movement that will be converted into electrical energy by a built-in generator.

The yellow-topped component of Aquamarine Power's Oyster device will face upwards from the seafloor when unfolded from the base

Ocean current to electric current

Inside the technology producing power at sea



Journey to shore
Electricity is carried along or beneath the seafloor. These cables connect generators to the land, where the energy can be distributed.

Flashing beacon
A light at the top of each float alerts boats to the presence of the wave-energy farm to help prevent collisions.

Cable connection
A cable connects the buoy to the seabed. As its float moves with the water, the cable is stretched and moved up and down.

Secure anchor
The device is securely bolted to the seafloor so that it remains effective in stormy conditions.

Magnet movement
A magnet is situated at the centre of the generator. It is attached to the cable, allowing it to move with the waves.

Wire coils
Wire is coiled around the magnet, but remains fixed to the generator so that the magnet moves through the coil repeatedly, generating an electric current.

AR ZONE! SCAN HERE

© Illustration by Nicholas Forder

High-tech classrooms of the future

Could these technologies soon become the norm in your school?

3D printers

Why bring in something for show and tell when you can print it in class? From geometry to anatomy, 3D printing offers a unique opportunity to print out customised educational tools and models to explore a wide range of school subjects. 3D printing has already revolutionised manufacturing around the world – around 80 per cent of high-tech manufacturing relies on 3D printing for prototyping in the US. Lessons in 3D printing may soon have to become the norm, especially in lessons in engineering and computer-aided design (CAD). Currently, 3D printers aren't strange to see in classrooms around the world, though they're yet to be commonplace. In 2019, CREATE Education Project and Rolls-Royce teamed up to create the first Primary Education 3D Printing Hub to support schools around the UK with access to 3D printing.

VR field trips

Could future field trips be held in the virtual world? Virtual and augmented reality have already proven themselves to be exciting new educational tools, allowing students to access new visual learning tools. This could soon extend to taking students on immersive field trips without the need to travel. Companies such as Nearpod and ClassVR are making it so VR can transport students to international sites. From the Pyramids of Giza to the outer reaches of our Solar System, students could be instantly transported to the many wonders of this world and beyond. The rollout of 5G connectivity could also play a large part in the success of VR in classrooms. Thanks to its ability to ferry large amounts of data, 5G would allow high-definition remote VR headsets to function without being tethered to desktop computers.

AI teaching assistant

Artificial intelligence continues to infiltrate many different areas of industry, but could that include your classroom? Although we are many years away from having a cyborg teacher at the head of the class, AI's current role is more on the administrative side, distributing homework, offering feedback on work and supporting a human teacher-led class. China's education system has been the first to truly embrace the technology of AI-assisted tutoring. Companies such as Squirrel AI Learning are delivering both AI online lessons from home and in high-tech tutoring centres for advanced one-on-one tutelage. In its first five years, Squirrel AI has opened 2,000 learning centres and registered over a million students.

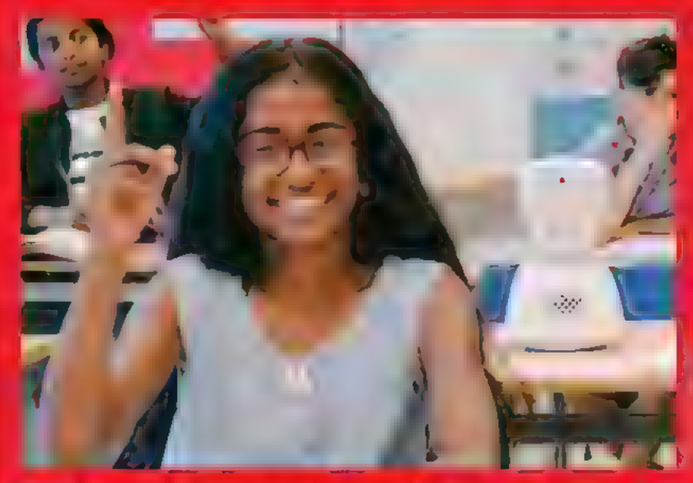
A Squirrel AI Learning platform at the 2019 World Artificial Intelligence Conference

Interactive teaching

In a world where we get our information from multiple sources, classrooms may adapt to include interactive technologies such as multi-touch screens. Studies at Harvard University have found that the traditional 'chalk and talk' method of teaching is less effective than active learning. This includes collaborative work on interactive devices, such as touchscreens, and augmented reality. In the future, the single-contact touchscreens of smartboards may be replaced by large-scale multi-touch and multi-user LCD screens. This advanced technology would allow multiple students to research, present and display educational tools and information at the same time. It would essentially be a wall-sized iPad that several students could use at once. At the moment, multi-user screens of this kind are predominantly being offered for corporate use by tech giants such as Panasonic, albeit on a smaller scale. In the future, these highly interactive screens may make their way into the classroom.

Robotic classmate

If we've learnt anything over the last year, it's the importance of education and helping those that can't physically come together to learn. However, this isn't a new hurdle for children with long-term illnesses unable to attend class. In 2018, the Hospital and Outreach Education project in the UK was granted £522,142 (around $730,000) to provide continued education to children with a long-term illness until they're able to attend school. This money helped to further the development of anti-isolation robot AV1, created by Norwegian company No Isolation. This small classroom stand-in allows children at home to listen, watch and communicate during a lesson. The robot lets children engage in lessons and interact with their peers from the safety of their homes or hospital beds. AV1 is operated through an app so the child can control its movements, microphone and speaker. These telepresence robots are growing in popularity in many different industries. For example, they will appear at the next Olympics to provide people with remote attendance.



AV1 allows children to engage in lessons without the need to physically be at school

Cloud computing

Cloud computing has changed the way many of us work and operate online during this global pandemic, and will continue long after it's over. For schooling, the ability to have all your work saved and accessible from the cloud not only increases remote accessibility to lessons but means you can never use the classic 'the dog ate my homework' excuse again. Cloud computing not only improves the way work is stored online, but may grow the number of students in a class, potentially from around the world through distanced learning. This upgrade to the way students learn and work may eventually lead to tablets replacing the humble pen and paper in classrooms. This would also support the growing trend in game-based learning, which is projected to jump in value from $3.5 billion (£2.5 billion) in 2018 to around $24 billion (£18 billion) by 2024.

AR ZONE! SCAN HERE

ENVIRONMENT

MASS EXTINCTION

THE DEATH OF THE DINOSAURS WAS JUST ONE OF FIVE GLOBAL EVENTS THAT SAW MILLIONS OF SPECIES WIPED OUT – HOW DO THESE EVENTS HAPPEN?

Words by **Scott Dutfield**

© Alamy

By the end of the Ordovician Period the seafloor was teeming with shelled creatures such as trilobites

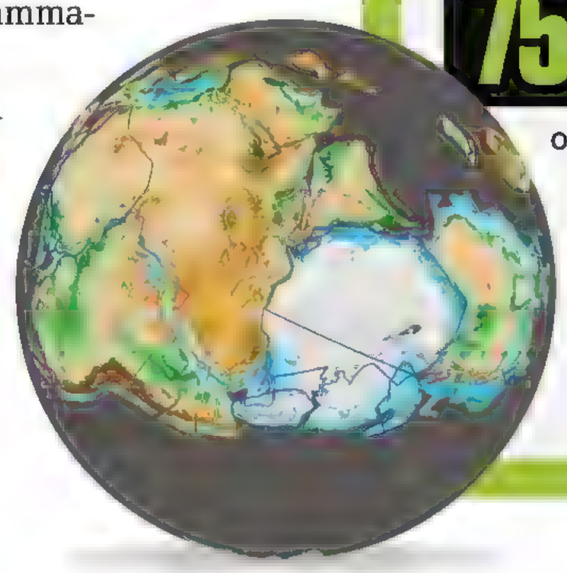
Ordovician-Silurian extinction

AROUND 440 MILLION YEARS AGO

Species made extinct 85%

The first mass extinction occurred when life itself was still in its infancy. Organisms such as corals and shelled brachiopods filled the world's shallow waters, but hadn't yet ventured onto land. When a climatic shift caused sea temperatures to change, the majority of life in the ocean died. By the end of the Ordovician Period, the rapid onset of mass glaciation covered the southern supercontinent, Gondwana. Glaciation on this scale locked away high percentages of the world's water and dramatically lowered global sea levels, which stripped away vital habitats from many species, destroying food chains and decreasing reproductive success. It's thought that the cooling process may have been triggered by the formation of the North American Appalachian Mountains. Large-scale erosion of these mountainous silicate rocks is associated with the removal of carbon dioxide from the atmosphere, which keeps the planet warm.

Alternative theories suggest that toxic metal may have dissolved into ocean waters during a period of oxygen depletion, wiping out marine life. Others suggest that a gamma-ray burst from a supernova ripped an enormous hole in the ozone layer, allowing deadly ultraviolet radiation to kill life below.



The supercontinent Gondwana reached the South Pole by the late Ordovician Period

Source: Wiki/Fama Camosa

Gondwana moves south

How a supercontinent changed life on Earth

560 MILLION YEARS AGO

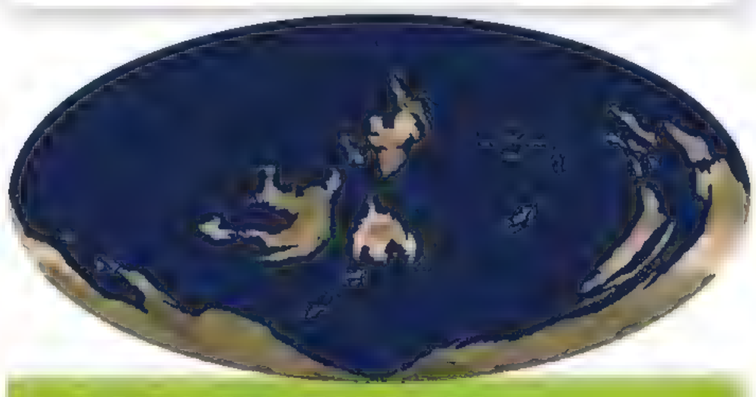
Thawing out

The Earth began to thaw out after a global ice age, flooding areas of land with water and raising global sea levels. This allowed marine life to flourish and diversify.

500 MILLION YEARS AGO

Heading southward

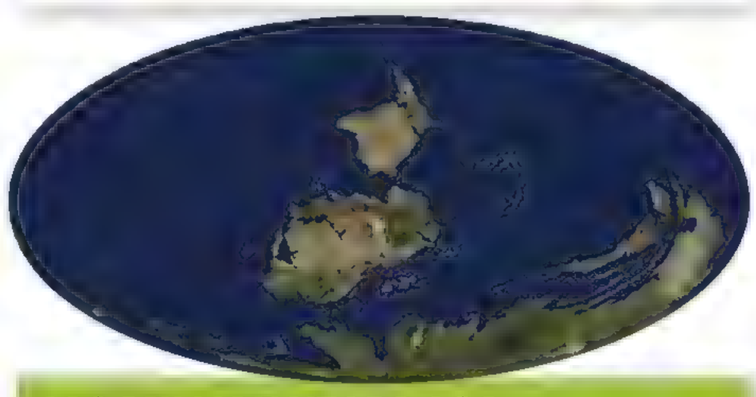
The supercontinent Gondwana, made up of present-day South America, Africa, Arabia, Madagascar, India, Australia and Antarctica, gathered at the South Pole.



440 MILLION YEARS AGO

Glaciation

Mass glaciation carved into Gondwana and caused sea levels to sink, reducing habitats and decreasing ocean oxygen. This led to the first mass extinction of marine life.



400 MILLION YEARS AGO

New life

Gondwana thawed and ascended to the equator. Diverse marine life returned to the oceans, and some species evolved to live on land, such as the first known insects.

© The Planetary Habitability Laboratory @ UPR Arecib

Late Devonian extinction

AROUND 365 MILLION YEARS AGO

Species made extinct 75%

Often referred to as the 'age of fish', the Devonian Period saw the rise and fall of many prehistoric marine species. Although by now animals had begun to evolve on land, the majority of diverse life swam through the oceans. That was until vascular plants, such as trees and flowers, caused a second mass extinction. As plants evolved roots, they inadvertently transformed the land they lived on, turning rock and rubble into soil. This nutrient-rich soil then ran into the world's oceans, causing algae to bloom on an enormous scale. This essentially created giant 'dead zones', which are areas where algae strips oxygen from the water, suffocating marine life and wreaking havoc on marine food chains. Species that were unable to adapt to the decreased oxygen levels and lack of food died. One such sea monster that was wiped from the world's oceans was a ten-metre-long armoured fish called Dunkleosteus. As a fearsome predator, this giant fish had a helmet of bone plates that covered its entire head and created a fang-like cusp on its jaw.

AR ZONE!

Death by volcano

How massive eruptions caused the biggest mass extinction on Earth

Eruptions
A plume of magma sitting below the crust in modern-day Siberia broke through the surface and erupted in violent explosions.

Acid rain
Sulphur dioxide within the clouds, formed by volcanism, precipitated as acid rain.

Global warming
Large amounts of carbon dioxide and methane were cast into the atmosphere, creating a global greenhouse effect.

Habitat loss
Rising temperatures, acid rain and wildfires stripped many species of their habitats.

Algal bloom
An influx of nutrients from erosion led to algal blooms developing, which absorbed much of the oxygen from oceans, called anoxia.

Erosion
Acid rain caused the erosion of the surrounding land masses, which would have caused excess nutrients to enter the oceans and feed algae.

Acidic oceans
Oceans became more acidic, as well as increasing in temperature by as much as ten degrees Celsius.

AR ZONE! SCAN HERE

Permian-Triassic extinction

AROUND 252 MILLION YEARS AGO

Species made extinct
96% marine life
70% terrestrial life

This extinction event, often referred to as the 'Great Dying', is the largest to ever hit Earth. It wiped out some 90 per cent of all the planet's species and decimated the reptiles, insects and amphibians that roamed on land. What caused this catastrophic event was a period of rampant volcanism. At the end of the Permian Period, the part of the world we now call Siberia erupted in explosive volcanoes. This released a large amount of carbon dioxide into the atmosphere, causing a greenhouse effect that heated up the planet. As a result, weather patterns shifted, sea levels rose and acid rain beat down on the land. In the ocean, the increased levels of carbon dioxide dissolved into the water, poisoning marine life and depriving them of oxygen-rich water. At the time the world consisted of one supercontinent called Pangaea, which some scientists believe contributed to a lack of movement in the world's oceans, creating a global pool of stagnant water that only perpetuated carbon dioxide accumulation. Corals were a group of marine life forms worst affected, it took 14 million years for the ocean reefs to rebuild to their former glory.

Some of the earliest land dinosaurs, such as dimetrodons, were among the first to become extinct

Triassic-Jurassic extinction

AROUND 201 MILLION YEARS AGO

Species made extinct
80%

During a time when dinosaurs had begun to dominate the world, the Triassic Period erupted in new and diverse life. Unfortunately, what may have also erupted was many more volcanoes. Although it remains unclear exactly why this fourth mass extinction occurred, it's thought that massive volcanic activity occurred in an area of the world now covered by the Atlantic Ocean. Similar to the Permian extinction, volcanoes released enormous amounts of carbon dioxide, forcing climate change and devastating life on Earth. Global temperatures increased, ice melted and sea levels rose and acidified. As a result, many marine and land species became extinct, including large prehistoric crocodiles and some flying pterosaurs. There are alternative theories that suggest rising carbon dioxide levels released trapped methane from permafrost, which would have resulted in a similar series of events that led to this mass extinction.

Ticinosuchus was one of many species to go extinct at the start of the Jurassic Period

K-T extinction

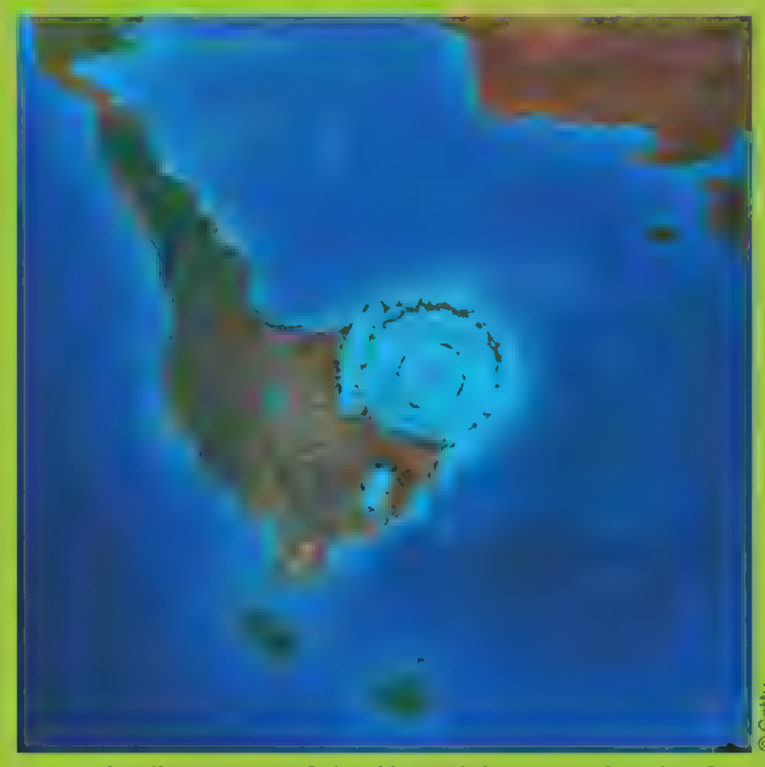
AROUND 66 MILLION YEARS AGO

Species made extinct 75%

The most famous of all five mass extinction events is the Cretaceous-Tertiary extinction – known better as the day the dinosaurs died. Geologists refer to the event as the 'K-T extinction' because the letter 'C' is shorthand for a previous geological period called the Cambrian.

Crash-landing into what is today Yucatán, Mexico, an asteroid over eight miles wide plunged into Earth at around 45,000 miles per hour. This punched a hole 110 miles wide and 12 miles deep, called the Chicxulub crater. The impact would have scorched all the land around it within 900 miles, and ended the 180-million-year reign of the dinosaurs on Earth.

What followed the impact was months of blackened skies caused by debris and dust being hurled into the atmosphere. This prevented plants from absorbing sunlight, they died out en masse and broke down the dinosaurs' food chains. It also caused global temperatures to plummet, plunging the world into an extended cold winter. It's estimated that it would have only taken months after the impact for most of the extinctions on Earth to occur. However, many species that could fly, burrow or dive to the depths of the oceans survived. For example, the only true descendants of the dinosaurs are modern-day birds – more than 10,000 species are thought to have descended from impact survivors.



© Getty

An illustration of the Chicxulub crater shortly after its formation 66 million years ago

Deep impact

How an asteroid brought about the end of the world for the dinosaurs

Acid clouds
Around 325 billion tonnes of sulphur gas was thrown into the atmosphere, which later fell to the ground as acid rain.

Explosion
The force generated by the impact created an explosion equivalent to 100 trillion tonnes of TNT.

Climate change
In the years that followed the impact, global temperatures plummeted by more than 30 degrees Celsius.

Wildfires
Everything within 900 miles was consumed in flames.

Wall of water
Upon impact, tsunamis up to 300 metres high surged around the world.

Earthquakes
A magnitude 10 earthquake tore through the seafloor – a magnitude yet to be recorded in human history.

All non-avian dinosaurs were killed in the fifth mass extinction

© Getty

Pandas became the poster species for extinction back in the 1980s, when there were fewer than 1,114 individuals recorded in China

© Getty

Holocene extinction

AROUND 8,000 BCE TO PRESENT

Species made extinct

?

Also known as the sixth mass extinction, for the last 10,000 years Earth has been in the midst of another extinction event, which is rapidly removing animals from our planet.

Scientists define a mass extinction as around three-quarters of all species dying out over a short geological time, which is anything less than 2.8 million years. Right now we find ourselves at the beginning of the latest mass extinction, which is moving much faster than any of the others. Since 1970, the populations of vertebrate species have declined by an average of 68 per cent, and currently over 35,000 species are considered to be threatened with extinction. During the 20th century alone, as many as 543 land vertebrates became extinct.

ARE HUMANS TO BLAME?

Humankind is always at the end of a pointed finger when it comes to casting blame for the climate crisis. Ever since the pollutant-pumping industrial revolution in 1760, humans have been the main contributor to Earth's current environmental crisis. From greenhouse gas emissions and ozone depletion, to deforestation, the plastic pile-up and the illegal animal trade, we have actively stripped the world of some species, and threatened many more.

There are those that argue climate change and the extinction of animal species are a natural part of life, and in some ways that's true. After all, the first five mass extinctions occurred

On the brink

THERE ARE THOUSANDS OF SPECIES THAT ARE IN DECLINE

This map shows some of the results from a study of 29,400 species of terrestrial vertebrates (animals with spines), outlining the distribution of 515 species that are on the brink of extinction, with less than 1,000 individuals seen on this map. The colour chart indicates the number of species in a 38-square-mile global cell grid.

without the presence of people. However, the difference is the speed at which these mass extinctions happen.

Fossil records don't just tell us what creatures existed before us, but also how long a species can naturally survive before becoming extinct, without human interference. This is referred to as the background rate, which is set at around a million years. Currently, because of human activity, this background rate is tens of thousands of times higher, meaning species are becoming extinct much faster than they should be. Studies have found that some species lost from Earth would have continued to survive for 800 to 10,000 years without the interference of human activities.

PANDEMIC PERSPECTIVE

Never before has the world been able – if not forced – to take a step for normal life and give nature the breathing room it needs. 2020's lockdowns led to a 17 per cent global decrease in carbon emissions, and a 20 per cent fall in nitrogen oxide levels. Waterways cleared up and animals were seen venturing into cities and towns around the world. While it appears a wonderful revival for the planet, it's a temporary one as human civilisation returns to normal and extinctions return to their previous rate.

Ecotourism is an industry that fuels conservation efforts worldwide, and since global travel restrictions were imposed, it's on the verge of collapse. Without the income of tourists, conservationists aren't able to help protect vulnerable species from poaching, which during the pandemic has been on the rise. Rhinos in Botswana, wild cats in South America and tigers in India have all been targeted over the last year.

Aerial view of deforestation in the Amazon caused by the growing demand for agricultural areas

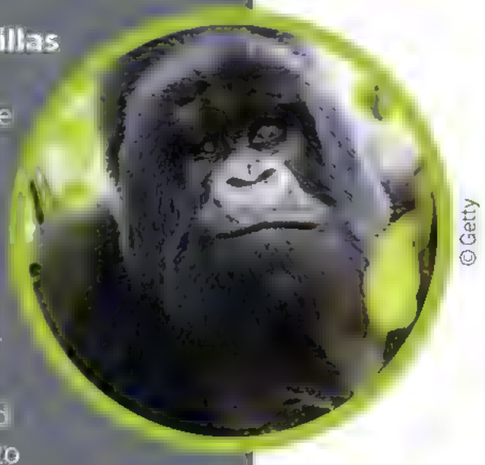
© Getty

5 FACTS ABOUT ALMOST-EXTINCT SPECIES

1 Javan rhino
There are only 74 wild individuals left in the world, which live on the Indonesian island of Java. These armoured giants once roamed throughout Asia and northeast India just 150 years ago.

© Alamy

2 Mountain gorillas
Nesting in the dense forests of the Congo Basin, mountain gorilla numbers are currently just over 1,000. This is an increase compared to previous years, but habitat loss and hunting continues to threaten their existence.



© Getty

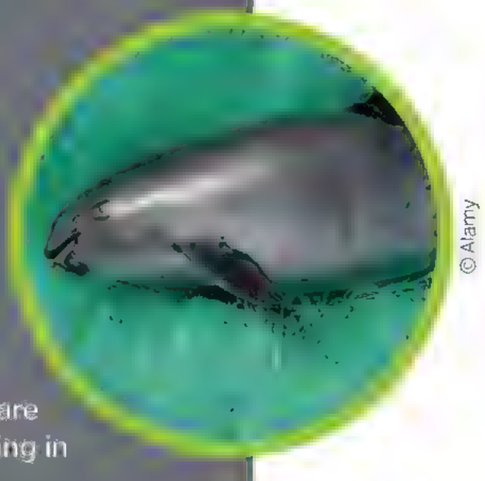
3 Asian elephant
In just 75 years the population of Asian elephants has dropped by roughly 50 per cent, with around 50,000 remaining in the wild.

© Getty

4 Orangutan
Around 100 years ago there were more than 230,000 of these orange apes swinging through the trees. Current estimates put wild Bornean populations at 104,700 and Sumatran numbers at only 14,000.

© Getty

5 Vaquita
The rarest marine mammal, these little porpoises are on the verge of extinction, with just ten known individuals swimming through Mexico's Gulf of California. Vaquita are killed by illegal fishing in protected areas.



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Turning back the clock

HOW SCIENCE IS TRYING TO SLOW DOWN THE SIXTH MASS EXTINCTION

Humans might be the driving force behind this accelerated extinction event, but we are also the answer to stopping it. The world is awash with scientists, conservationists and environmentalists working in both the laboratory and in political battlegrounds to protect endangered species.

From tackling global pollution emissions in the 2016 Paris Agreement to the UK's Global Resource Initiative that combats deforestation, legislation will always be at the forefront of the fight against mass extinction. In particular, one of the biggest direct threats to endangered life is the illegal animal trade.

In wake of the current global pandemic, wildlife markets have been put into the spotlight as not only being environmentally irresponsible, but potentially dangerous to human health through zoonotic diseases – those that jump from animals to humans – such as COVID-19. These markets are found throughout the world and trade live exotic animals or products derived from them. For example, China's bear farms cage 20,000 Asiatic black bears for their bile, resulting in the wild population declining.

Lawmakers are tackling these kinds of markets with growing success. In Vietnam, for example, Prime Minister Nguyen Xuân Phúc signed a new directive that bans wildlife imports and closes illegal wildlife markets.

NEW EYES IN THE SKY

One of the best ways to help prevent species from becoming extinct is to monitor their populations and identify any problems before it's too late to help. Currently camera traps and surveys conducted on foot or from aircraft are the main method of data collection. However, recent research has used a combination of satellite imagery and artificial intelligence to observe animals from space. Using high-resolution aerial photographs of Africa's grasslands, researchers created an algorithm to sweep over thousands of miles and count every elephant pictured in the blink of an eye. The technology is still in its infancy and is limited to areas where large animals, such as elephants, aren't obscured by forest habitats.

SAVED BY CLONING

Another potential solution to combat extinction could be to clone species. In February 2021, scientists revealed they had successfully cloned a black-footed ferret, from an animal that had died more than 30 years ago. Native to North America, these small mammals were thought to be extinct until a small colony was found in the early 1980s, which were entered into a breeding program and reintroduced around America. Due to inbreeding, the population of around 650 ferrets is at risk of extinction once again. This inspired researchers to create a genetic copy from the preserved cell of a wild female, named Willa, who died in the 1980s. The process of cloning was similar to that used to clone Dolly the sheep back in the early 1990s. Scientists hope that after time spent in captivity, cloned members of the species can successfully re-enter the wild, offering a new conservation tool to protect endangered species.

It is legal, scientific and technological advances such as these that will help to conserve Earth's wildlife and hopefully slow down the sixth mass extinction.

The first cloned black-footed ferret, called Elizabeth Ann

Tracking elephants

How satellites can help us monitor animals from space

Eyes in the sky
Images were taken by DigitalGlobe's satellites WorldView-3 and 4, which provide commercially available photographs.

Snapping the savanna
Satellite imagery of Addo Elephant National Park in South Africa was used for the AI algorithm to analyse.

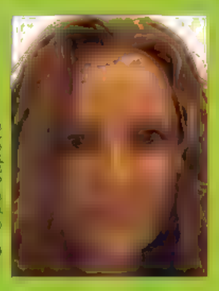
Who's who
The algorithm is trained to identify elephants based on a set of parameters related to the characteristics of the elephants.

An aerial image of Addo Elephant National Park, showing the algorithm counting elephants

Quick maths
The AI can count the elephants in each satellite image within seconds. On average, it would take a human 20 minutes to count the same number of elephants.

Saving animals from space

DR OLGA ISUPOVA, CREATOR OF THE ELEPHANT-TRACKING AI, TELLS US HOW THIS TECHNOLOGY COULD BE USED IN THE FUTURE



Dr Olga Isupova

CAN THE AI BE APPLIED TO DIFFERENT SPECIES?
Yes. We are currently looking to get a hold of data to test the same approach on rhinos. The main question here would be the size of the animals and their habitats. We can't see through clouds, obviously, but also we can't see through forested areas. Therefore we can't look for animals that are in dense forest. If they're in open areas, then it's just a question of their size.

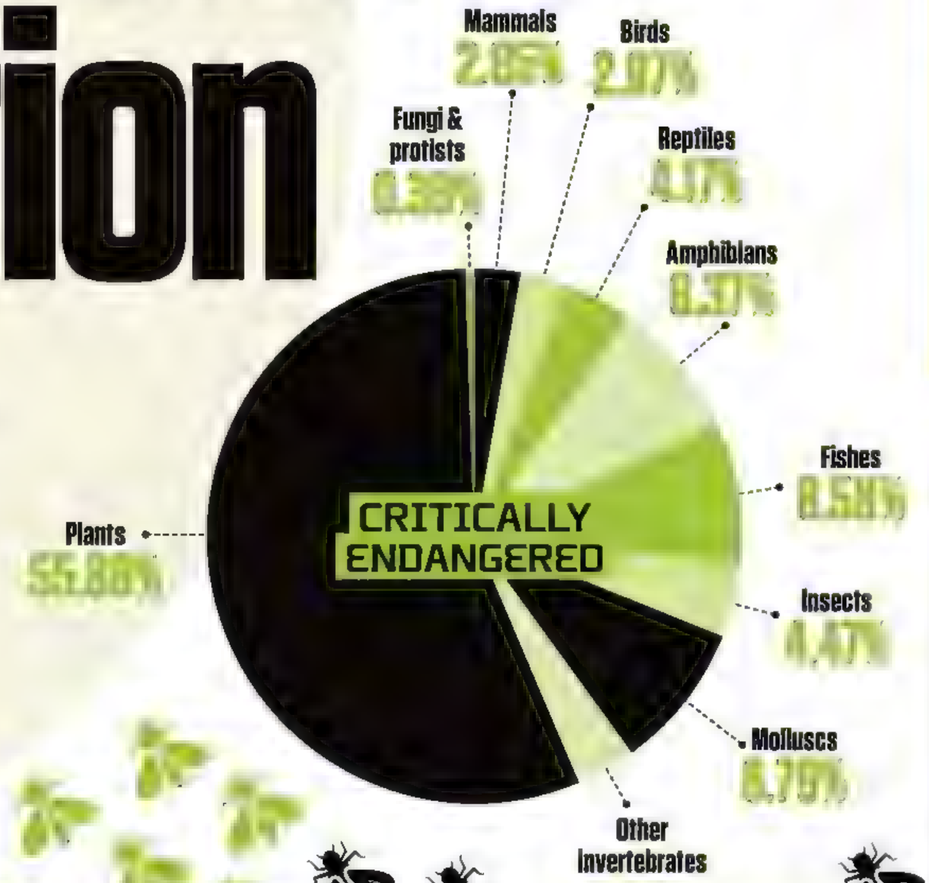
IS THE AI COMPLETELY LIMITED BY ANIMAL SIZE, OR COULD IT POTENTIALLY BE ADAPTED TO SPOT SMALLER SPECIES?
It depends on the resolution of the satellite, and it also depends on the machine learning algorithm performance. We are currently looking at how we can improve the algorithm itself to look specifically for smaller objects. We could also look for those animals who appear in herds. For example, with penguin colonies, the model can detect the whole colony and then have an additional algorithm that approximates the count based on the size of the colony. Also, you can look for the footprints of the animals. The animal itself can be quite small, but if there are many of them and they leave lots of footprints after them, we can also try to track that.

"If they're in open areas, it's just a question of their size"

Getty

The state of the sixth mass extinction

The International Union for Conservation of Nature (IUCN) comprises a number of government and civil organisations and is the leading voice on global wildlife extinctions. It collects a host of information on each species, from diets and habitat to distribution and population status. All species are assessed by the IUCN Red List and are classified according to their risk of extinction: least concern, near threatened, vulnerable, endangered, critically endangered, extinct in the wild and finally, extinct. The information presented here is the result of a 2020 Red List summary.



CRITICALLY ENDANGERED
221

ENDANGERED
539

Mammals

CRITICALLY ENDANGERED
30

ENDANGERED
82

VULNERABLE
557

Fungi and protists

CRITICALLY ENDANGERED
4,337

Plants

ENDANGERED
7,925

VULNERABLE
8,098

VULNERABLE
127

CRITICALLY ENDANGERED
347

ENDANGERED
690

Insects

VULNERABLE
811

CRITICALLY ENDANGERED
666

Fishes

VULNERABLE
1,338

ENDANGERED
1,036

ENDANGERED
1,036
Amphibians

VULNERABLE
704

CRITICALLY ENDANGERED
650

VULNERABLE
1,032
Molluscs

ENDANGERED
586

CRITICALLY ENDANGERED
682

VULNERABLE
541
Reptiles

ENDANGERED
584

CRITICALLY ENDANGERED
324

VULNERABLE
712

ENDANGERED
347
Other invertebrates

VULNERABLE
798
Birds

CRITICALLY ENDANGERED
282

ENDANGERED
460

CRITICALLY ENDANGERED
223

IUCN assessed species
81%

IUCN ASSESSED SPECIES
Current: **128,918**
Goal: **160,000**

Totals

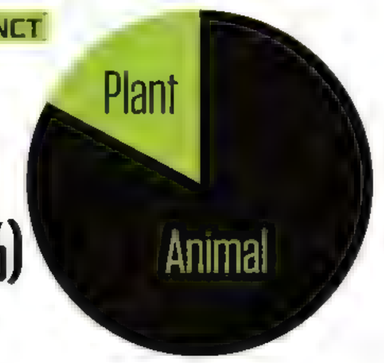
CRITICALLY ENDANGERED
7,762

ENDANGERED
13,285

VULNERABLE
14,718

TOTAL
- 35,765 species are threatened with extinction
- That's 28 per cent of all species assessed

NUMBER OF SPECIES EXTINCT
982
Animal: **817 (83%)**
Plant: **165 (17%)**



An earthquake can render a town unrecognisable

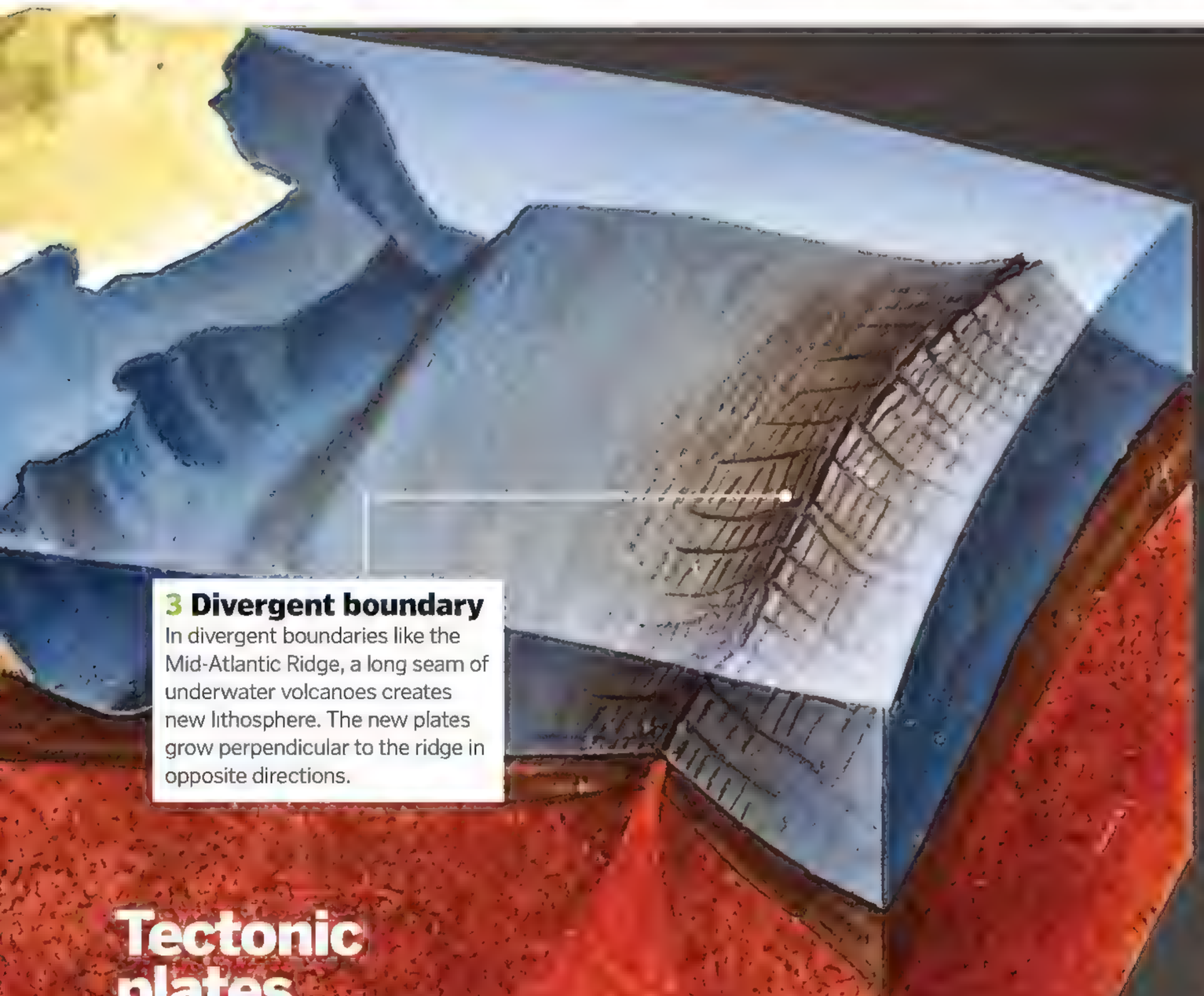
Earthquakes

Earthquakes are not-so-subtle reminders that the Earth is very much alive – and kicking

Our planet isn't the solid hunk of rock it appears to be. It is a shifting, boiling, sliding, sinking, churning ball of superheated magma with a thin, brittle skin. This skin, called the lithosphere, is fractured into 15 large and small segments called tectonic plates. The deep, molten seas of Earth's mantle are home to giant convection currents that push magma upward and outward.

The tectonic plates float atop these vast subterranean currents, bumping and grinding against each other as they jostle for position. As they move around they forge cascading mountain ranges, deep oceanic gorges and strings of volcanic islands.

Imagine two colossal hunks of rock – some the size of whole continents – trying to scrape past each other, or indeed over each other. The jagged edges of the plates periodically get jammed together, storing up tremendous potential energy along cracks called fault lines. When the rock finally gives way, the plates slip and



3 Divergent boundary
In divergent boundaries like the Mid-Atlantic Ridge, a long seam of underwater volcanoes creates new lithosphere. The new plates grow perpendicular to the ridge in opposite directions.

Tectonic plates explained

Understanding how earthquakes happen

The Earth's tectonic plates

Afloat on a sea of magma

Divergent boundaries

These are long seams of volcanoes – usually deep under the ocean – where the Earth's crust is formed. Plates grow away from each other at a rate of 2.5 centimetres per year.

Subduction zones

When two plates converge, one slowly plunges under the other, swallowing up the Earth's crust. Subduction zones are the world's most active earthquake and volcano hotspots.

Plate movement

Convection currents from the Earth's molten core rise towards the surface and spread outward. The brittle lithosphere rides this subterranean sea of magma like a conveyor belt.

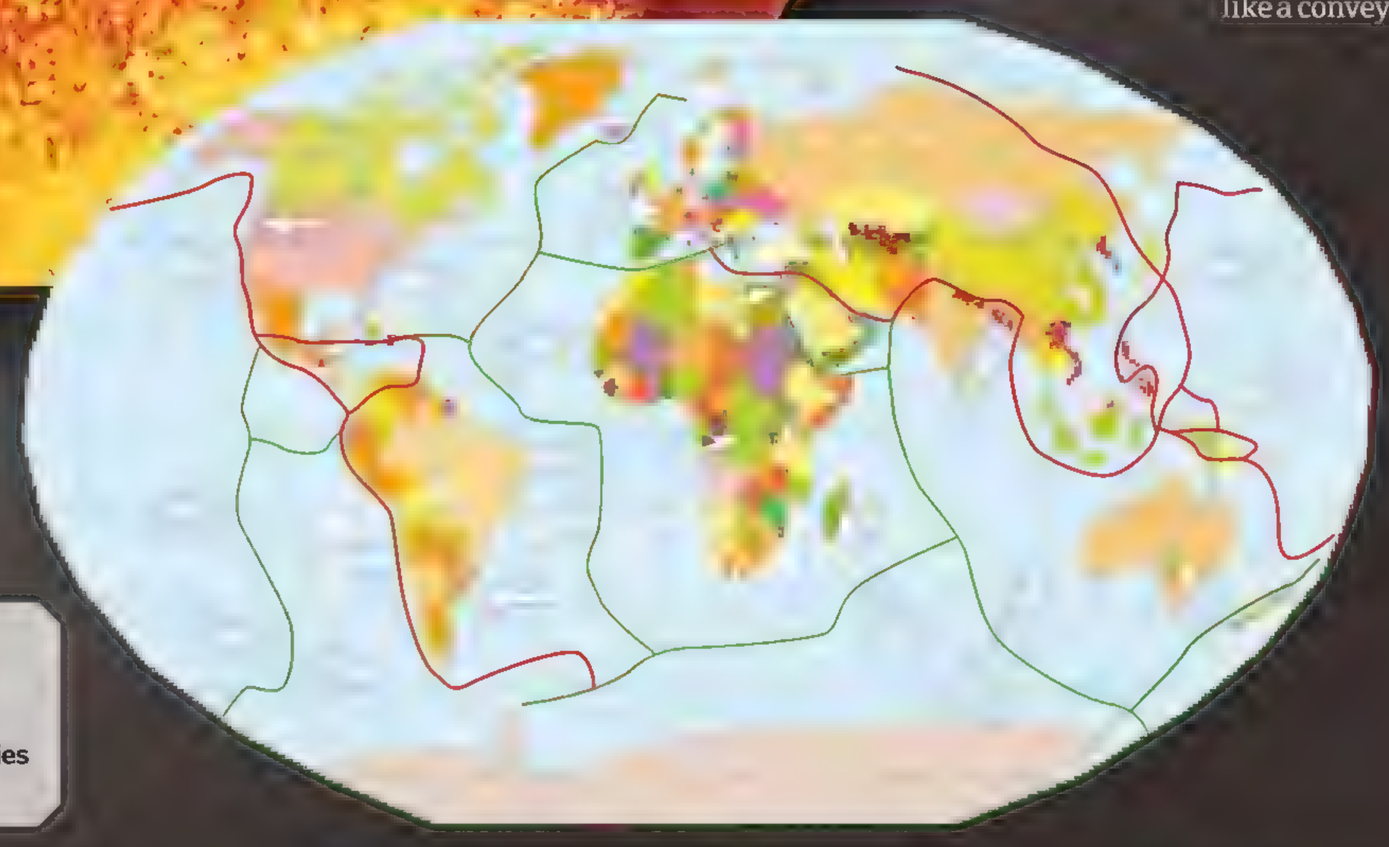


PLATE KEY
Earth's plate layout
- Subduction zones
- Divergent boundaries
- Plate movement

dip violently along the fault, releasing megatonnes of stored energy as seismic waves.

Originating at the focus of the fracture – tens or even hundreds of kilometres below the surface – seismic waves ripple outward in all directions. High-frequency body waves travel quickly through liquid and rock, but do little damage. It's the lower frequency surface waves – which twist, roll and tear the crust like paper – that end up causing the most devastation.

Using ultra-sensitive seismographs, geologists estimate there are 500,000 earthquakes every year, although only about 100 of these do enough damage to make headlines. But when the big ones strike, they are the world's deadliest geological phenomena.

Undersea earthquakes can trigger killer tsunamis that travel across the ocean faster than a high-speed jet. They cause massive avalanches and landslides, and in some areas loose, waterlogged soils can become 'liquefied', causing homes and high-rises to sink into their foundations. In poorer developing countries, even moderate quakes are often enough to topple poorly constructed buildings including schools, churches and hospitals.

Head to head

THE BIGGEST AND BADDEST EARTHQUAKES OF ALL TIME

LONGEST

The Sumatra-Andaman quake

When: 2004
Facts: The quake that triggered the catastrophic Indian Ocean tsunamis of 2004 lasted between eight and ten minutes – an eternity for an earthquake.

MOST POWERFUL

Valdivia quake

When: 1960
Facts: A 9.5-magnitude quake off the coast of southern Chile wrought death and destruction as far away as the Philippines, Hawaii and Japan.

DEADLIEST

Shaanxi quake

When: 1556
Facts: An 8.3-magnitude quake in Shaanxi, China, ripped open 20-metre crevasses, triggered landslides and levelled homes for 300 miles, killing an estimated 830,000 people. It also damaged the Small Wild Goose Pagoda, built between 707 and 709.

INSIDE BEEHIVES AND WASP NESTS

Words by Ailsa Harvey

From building alone to serving royalty, these insects work tirelessly to create their perfect homes

It's usually around the summer months that you're most likely to encounter bees and wasps. As these frantic flyers approach, expertly dodging waving hands as they buzz about the flowers, it can be difficult to understand the lives of these busy insects.

But there's a good reason why you might forget about bees and wasps during the winter. Although many of them are still around, they are in hiding. Some have spent the entire year leading up to winter ensuring that their crowded nests are prepped for months in shelter. That sugary drink or picnic platter you introduced to their garden territory may have even played a small part in the growth of their nests.

The homes of bees and wasps are generally well hidden in rocks, trees and below the ground. The fact that you can't see them means that their predators are less likely to be able to as well. But if you were to access them, some would be teeming with activity, some would centre on a glorified ruler and others would house larvae left to fend for themselves.

With over 20,000 species of bee and 30,000 wasp species, each has developed a unique nesting system. A crowded social space isn't for every species, and not every bee or wasp in a colony gets to reap the rewards of their build. One thing that the majority of these insects do share is their dedication to work. Each role carried out by individuals in these habitats contributes to the insects' survival. With some species, the effort they put in to produce these architectural wonders provides benefits to us humans as well. Wasps act as pest control as they hunt prey to bring to their nests, while bees continue the cycle of life by pollinating plants as they prepare for hibernation. To learn more about how and why bees and wasps act in the ways they do, we need to look inside their homes.

5 RECORD-BREAKING COLONIES

1 Biggest build
A 3.7 by 1.75 metre wasp nest found in Waimauku, New Zealand, in 1963 was the largest wasp nest ever found. The wood construction was so heavy that it fell from its tree, splitting in two.

2 Mega-queen
The biggest queen bee in the world belongs to the Wallace's giant bee species. The Indonesian queen bee is four times the size of a European honey bee, with a wingspan of over six centimetres.

3 Tiny flier
At less than two millimetres in size, *Perdita minima* is known as the world's smallest bee. It constructs miniature, solitary nests in the desert sands of the southwestern US.

4 Pub pests
The biggest wasp nest ever discovered in the UK was found in the attic of a pub in Southampton. The nest measured 1.8 by 1.5 metres and housed around 500,000 wasps.

5 Honey hoarder
Beekeeper Ormond Aebi reportedly broke the world record for the most honey obtained from a single beehive. In 1974 the beekeeper harvested 183 kilograms of the sugary substance.

This red mason bee is carrying mud to seal her nest

Red mason bees

One of around 200 of the planet's solitary bees, the red mason bee has to search for a suitable egg-laying location that doesn't need to be built from scratch. This species only flies 90 metres from its nest, so an area that provides the female's needs is essential. First on the list is a suitable cavity, such as a hollow plant stem, dead log or a crack in a rock face. Here she can lay her eggs. This makeshift nesting place needs to be close to a food and mud source. The single bee will carry mud to the space where her eggs lie, and use it to seal them in. If the bee has to travel long distances to find mud, her unborn young are placed at risk of predation.

The smaller males are laid near the front of the nest, and are first to emerge. After growing up and finding a mate, females will repeat the hard work of their mother, building nests alone for the offspring they won't live to meet.

Solitary nesters

Some of these insects' breeding grounds lack a certain social buzz

Grass-carrying wasps

The core component of a grass-carrying wasp's nest lies in the insect's name. These black, ant-like wasps pack hollow stems with nests of grass for their young to grow in. Cushioned and hidden between the blades, grass is used to create sectioned-off cells for each egg.

The first step for the female grass-carrier is to build the nest. Using her mandibles, she cuts the blades to the required size and carries this equipment to the nest. The building process also requires hunting. Stinging and immobilising her prey – usually tree crickets – the wasp embeds them in the blades of grass, ready for when her young need to eat. Wood can also be carried by these insects, placed between the eggs to create sections or at the end of the hollow to close it and protect the inhabitants.

Grass-carrying wasps' nests can be spotted as they fill small holes with multiple blades

Inside a honey bee hive

Take a peek at this bee's hierarchy in action and discover how their sweet treat keeps them buzzing year-round

If you ever needed an explanation for the phrase 'busy as a bee', just take a look inside this honey bee hive. The majority of honey bees are experts at working, since chores are all they know. From the moment they are born in these advanced hives until their final day, workers create and sustain these wax hives.

When temperatures get too high, they distribute water around their home and fan it with their wings, while if temperatures drop they huddle together and warm it with their bodies. They feed the future queen, source food for the winter and build and fill storage cells.

Some honey bees create this hive of activity and survival in the bark of a tree. The perfect location will have a naturally occurring hollow and entry route so that the bees don't have to dig their space before creating the cells.

Honey cells
The worker bees share the nectar brought back from nearby flowers, chewing it in order to mix it with their saliva. This contains an enzyme which will change the pH and other chemical properties required to produce honey. Honey is dried and stored in designated cells for food during the winter months.

Melting wax
The bees' wax-making glands produce beeswax, arranged in circular tubes. As they work, the heat from their bodies causes the cells to melt into hexagons.

Smart design
The hexagonal cells of the honeycomb are the most efficient shape to maximise the number of cells built, with minimal wax used and producing no gaps.

Pollen cells
Some cells are used to store pollen. This protein-packed food source is fed to worker bee larvae. As a bee matures, it needs less protein and depends on the sugar and carbohydrates of honey and nectar.

The queen's guards
The queen bee has a group of guard bees, who form a circle around her. They keep this formation, with some walking backwards with the queen to ensure that their heads are always facing her.

Leaving the hive
A bee's work lies beyond the hive. Visiting between 50 and 100 flowers in one outing, the worker bees will come back with their 'honey stomachs' – separate from their main stomach – filled with nectar.

Nurse bee
Nurse bees secrete food for the larvae. Worker bees are fed 'worker jelly' by the nurse bees, which includes a combination of pollen and honey, while a protein and sugar-rich 'royal jelly' is provided for queen larvae.

Worker bee larvae
In its designated cell, it takes 21 days for a fully formed worker bee to develop from an egg. These female worker bees begin their hive chores as soon as they are born, clearing their cell for a new egg.

Meet the queen bee

The queen is the largest, most powerful bee in the honey bee hive. Even superior to almost every bee she sees, she knows to calm her and respect the queen. When the queen nears the end of her life, worker bees feed large eggs for 10 to 20 potential replacements. However, there can only be one that dominates the hive.

The first act of the queen, after emerging from her cell, is to kill the other potential queens who were too close to gain the title. If two emerge at once, they battle to the death. The surviving queen has two main roles. One is to mate with the drone bees, and store their sperm to fertilise eggs throughout her life. The other is to produce 'the queen's signal'. Using 15 different glands, the queen produces pheromones. Similar to being put under a spell, these chemicals keep the colony working together and maintaining the hive.

Her pheromones can stop other females developing their ovaries, attract mates and bring the entire group together to follow her to swarm. Without these pheromones, the queen would lose her powers to create a sense of order, a peaceful hum and a hierarchy that benefits her, the others and the continuation of the species.

The nest of the yellowjacket

How does a single wasp raise a family of thousands?

A yellowjacket wasp nest grows rapidly in size over the course of a year, but drastically dies out during the winter months, with few survivors. Turning underground burrows, human-made structures and other cavities into wooden homes buzzing with life, the entrance to these wasps' nests is one place you don't want to mess with.

Yellowjacket wasps aren't afraid to sting. In fact, they are equipped to sting any trespasser who sets foot near the only entrance to their home and family. Born to defend these mighty structures, the nests of yellowjacket wasps and the thousands of buzzing bugs may lie right beneath your feet.

Repurposed burrow
One part of the nest that these wasps can't take credit for is the cavity. These are often old rodent burrows, which the yellowjackets use as their own.

Support root
Yellowjacket nests are often found under trees, as the roots can be used to secure the wooden nest. The entire structure often hangs from a strong root.

Wood structure
The nest is built using wood fibres, which the wasps mix with their saliva to create a paper-like material. Yellowjacket wasps create an envelope-like covering to encase the cells.

Protective aggression
Yellowjacket wasps are one of the more aggressive species. They are known to enter attack mode and sting when they believe the nest to be under threat.

Home for thousands
When the colony reaches its peak, the nest can provide shelter for up to 10,000 wasps.

Cell layers
The wood-based paste is used to sculpt layers of hollow cells. They can create these hexagonal shapes for around 200 eggs.

Queen cells
New queens are born in these larger cells. They appear towards winter so that they can leave the colony to mate.

Entrance
When hanging below ground, there is space underneath the nest. A gap in the outer envelope creates an access point for the wasps.

Wasp royalty

The yellowjacket queen puts in her fair share of hard work. As the only survivor over the winter months, it is her job to create a new nest. Having mated with male drone wasps, the queen finds a suitable location for her future colony. There she builds wooden cells to lay her eggs and goes foraging for food for them.

When the first of her offspring emerge, they become worker wasps and can help their queen to build the nest and grow the colony. Finally she can rest, knowing that others can continue her hard work.

[illegible] eggs in the cells, which are still being made. As the one fertile member of the group, the other wasps are very protective of their leader. They can become distressed and aggressive when they believe the queen to be in danger.

The yellowjacket queen is around seven millimetres longer than a yellowjacket worker

Seasonal cycles

What bees and wasps are up to through the year

SPRING

BEE
When temperatures rise above nine degrees Celsius, honey bees emerge from their hives. Having used much of the stored honey, they search for flowers.

WASP
The queen yellowjacket emerges from hibernation and searches for a safe place to build her nest. The eggs she lays hatch into larvae.

SUMMER

BEE
The hive reaches its peak size, increasing the influx of food to the honeycomb. After the longest day of the year, the bees start to prepare for hibernation.

WASP
The colony's first generation of workers grow into adults as the season starts. For the remainder of summer, the queen will stay in her nest.

AUTUMN

BEE
As winter approaches, mating season ends and new queens are not produced. Any drone bees that are still in the hive may be kicked out for winter.

WASP
Male wasps and new queen wasps grow in the cells. When fully grown, they will leave the nest to mate.

WINTER

BEE
All the winter bees are born before the beginning of this season. They huddle together in order to keep the temperature in the hive warm enough.

WASP
The male wasps die when winter approaches, while the fertilised female wasps go into hibernation and prepare to start a colony of their own.

Rocky shores explored

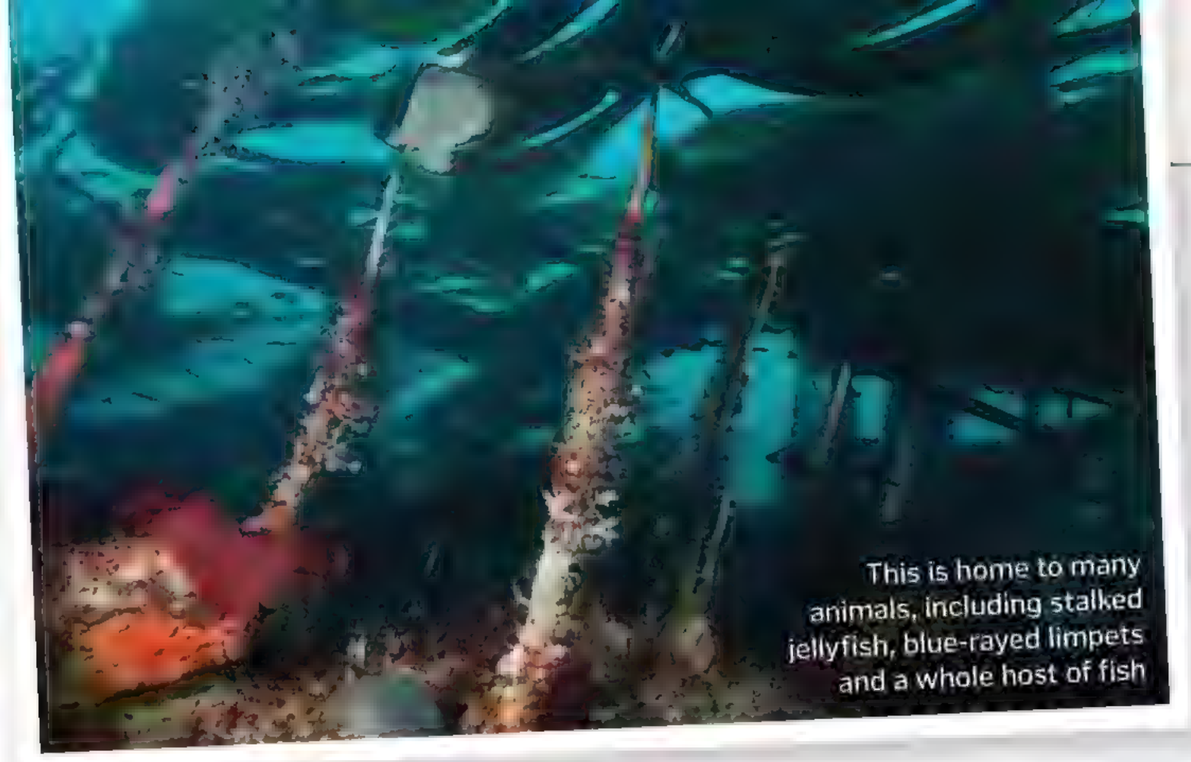
There's marine wildlife in every nook and cranny of the coast, just waiting to be discovered

Devil crabs, sea lemons and hares, squat lobsters and snakelocks anemones are just some of the things you might be lucky enough to see when exploring rocky shores around UK coastlines. There is something really special about heading to the shore not knowing what might be tucked away, lurking under rocks, seaweed and crevices. But you need to know where to look and what you're looking for, otherwise you could miss more than you spot.

Did you know the beach is divided into three main parts? There's the upper, middle and lower, with surprisingly different inhabitants in each neighbourhood, all with special adaptations to live there. What you see on the shore will give you clues to where you are, hints to the best places to find creatures and what they are.

From a distance the upper shore looks like a pretty barren place to live, with dull browns, greys and greens, but the animals found here are rock hard. Acorn barnacles, limpets and sea snails called periwinkles can live here quite easily, grazing the rocks and battling the elements. They have one main aim: not to dry out. Inhabitants must do all they can to survive out of water. The middle shore is full of richness, vibrant colour and packed with exciting finds: an abundance of crabs like the green shore crab, beadlet anemones, edible seaweeds and seaweeds that smell like pepper.

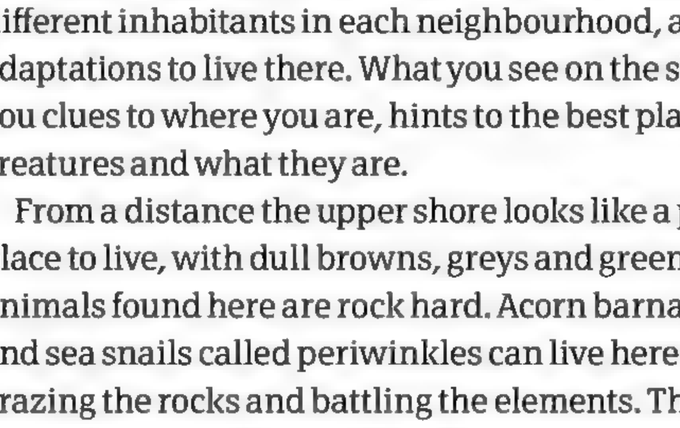
If you want to see some really cool stuff, try to get out when the tide is really low to see serrated wrack and velvet swimming crabs – called devil crabs because of their red eyes – that can give quite a nip to the fingers. But the most amazing kelps live here too. With wavy fronds that look like underwater trees, they're often referred to as kelp forests.



This is home to many animals, including stalked jellyfish, blue-rayed limpets and a whole host of fish

A good place to hide
Check under rocks and boulders, on and under seaweed, in crevices, overhangs and in rock pools to find animals.

Snakelocks anemone
Found low on the shore, by night they shine fluorescent green due to a special protein in their tentacles.



Middle-shore madness

This is a place you may have stumbled across before, and is full of a variety of different animals and plants. But with more species of [illegible] for [illegible] to spectacular heat. It's home to many beautiful anemones like [illegible] and tasty daisy anemones, which often open themselves wide [illegible] Despite them being just a blob, beadlet anemones are far more complex than they look. They can get very angry if something knocks their space – you wouldn't want to mess with one. If another comes too close, it will be [illegible] somewhere else, or falls off the rock. If you see these on [illegible] you won't be able to see their tentacles, which they use to catch food – they will be tucked away as a strategy to avoid drying out.

Areas of the rocky shore

By understanding these different areas and what lives there, you will find it easier to rock pool

What to spot

Only with big tides do these areas get covered with water. Look out for barnacles, sea snails and limpets.

Lichens and lots of rock

Not a huge amount can live here – there is very little water, and temperature and sunlight are very high.

Look for the seaweeds

Seaweeds are a really good way to tell what zone of the shore you're in. Channelled and spiral wrack are found here, in the upper shore.

Middle shore

Explore the middle shore for sea snails, anemones, limpets, crabs and mussels.

Surviving out of water

With a constant covering and uncovering of water, you'll mostly find animals hiding where they can keep wet and cool.

Urchins

Try to find green sea urchins here – they have purple tips to their spines.

"The most amazing kelps live here too"

AR ZONE! SCAN HERE

Limpet love

You may think limpets appear quite boring, but you'd be wrong. They are the sheep of the ocean, grazing seaweed off the rocks when the tide is in, making it less slippery for exploring. They move between their homes, called 'home scars', in between tides, sticking tight to the rocks when the tide is out so they keep nice and wet and are not eaten. But there is something truly amazing about them. The teeth of a limpet – yes, they have teeth – are made of the strongest natural material known to science, even stronger than spider silk.

What is a petrified forest?

How a forest of green trees turns to stone and rubble

Baking in the Arizona sunshine is a forest frozen in stone. Spanning 896 square kilometres, the Petrified Forest National Park is a vast, arid site filled with undulating hills and rocky outcrops all staying dry in the hot weather. But it wasn't always this way.

Travelling back more than 225 million years, the almost-barren land today once flourished with towering conifers and trickling rivers. However, during Earth's evolutionary journey to the modern day, the land was stripped of its once-luscious green foliage. Instead it has been left with the petrified shadow of a forest that once was. As if having stared into the eyes of Medusa, solid stone tree trunks litter the ground. They are the same trees that once stood tall in a living forest, but over time have undergone a type of preservation known as petrification.

Unlike the creation of tree fossils, where the carbon-rich wood is compacted by mounting mud and rocks, petrification is a process whereby minerals are displaced from one source and incorporated into the remains of a once-living organism. This form of natural preservation occurs not only in ancient trees, but across the spectrum of life on Earth. For example, the bodies of migrating birds that have fallen into Lake Natron in northern Tanzania have undergone a calcification whereby their remains are chemically preserved with calcium from the alkaline lake water – albeit in a much shorter time frame than the stone wood in the Petrified Forest. It's taken millions of years for the types of preserved wood found in Arizona to form, and it's not the only place in the world to showcase forests of the past. Throughout America and as far as Greece, these stone forests offer a glimpse into a world long forgotten.

Prehistoric forests
Conifer trees that once stood as lush, green forests in prehistoric Arizona reached heights of around 60 metres, concentrated near rivers and streams.

"Timber!"
When these trees died or were damaged they would naturally fall into the surrounding water systems.

Volcanic eruptions
Over time volcanic explosions caused tonnes of ash to enter into the atmosphere, settling into water that trees had fallen into.

Absorption
The minerals that make up volcanic ash, such as silica, are then soaked up by the submerged wood.

Turning tree trunks into stone

How volcanoes play their part in preserving wood over millions of years

© Getty

The National Park is a beautifully haunting sight

Colour of petrification

These elements give petrified wood its beautiful, glassy and colourful appearance

- Carbon, manganese
- Copper, chromium, iron
- Iron
- Natural quartz
- Copper, iron

Global shift

During this petrification process, the world's once-joined continents separated, changing the landscape and ultimately draining this area of water to reveal the now-stony remains of forests long forgotten.

Transformation

Over millennia the silica and other trace minerals, such as iron, crystallise into an array of coloured hard quartz.

AR ZONE!

Empty sound

How does this hollow structure make noise?

Button
This is produced the first time the young snake sheds its skin. It replaces the small, round end of its tail that it was born with, called a pre-button.

Upright position
More often than not, a rattlesnake will hold its rattle upright. This keeps it off the ground and protects it from damage.

Amplified sound
When the keratin segments strike each other, sound waves bounce off the walls of the rattle and echo in the hollow space.

Interlocked segments
Keratin rings have hooked ends to keep each segment connected.

Roaring rattles
Every time the snake sheds its skin, it leaves behind a new keratin segment. The more of these hollow spaces, the louder the rattle will be.

Shaker muscles
Strong 'shaker' muscles control the movement of the rattle. These can move 90 times per second and can continue to produce the sound for three hours.

Rattlesnakes can sense heat coming from their prey before they attack

Inside a rattlesnake's rattle

What gives these reptiles their distinguishing sound?

Found in a wide range of habitats across North and South America, rattlesnakes add a vibratory rattling sound to the landscape. From afar this might sound relaxing, almost meditative, but it often indicates that you're approaching danger. The rattlesnake shakes its rattle to warn off any animal it deems a threat, and it considers humans among these threats. When hunting for rodents and other food, the snakes can also use this rattle to distract animals before pouncing on them and making them their dinner.

Beyond its clattering chorus, this species of snake is equipped with toxic venom. However, rattlesnakes aren't usually fatal to humans. If you are unfortunate enough to suffer a bite, your symptoms would include pain and swelling, but you might not need hospital treatement. Most of the time rattlesnakes won't even release their venom when biting a human. This is because they don't bite us with the aim of killing and eating us, but do it to scare us away.

These sounds are a good indication of their presence, but it is a misconception that all rattlesnakes make this noise. Young snakes, for example, have an underdeveloped rattle that lacks the two segments required to produce a noise. And while it might sound and look like a maraca being shaken, there are no loose objects inside the rattle to create this noise.

The silent shake


Here you can see the siphon really clearly – their darting device

Inside a cuttlefish

The hidden secrets of why a cuttlefish is so fascinating

What's for dinner?

Their tentacles dart out to catch crabs, fish, prawns and other cuttlefish, helped by their many arms.

Shape-shifting cuttlefish

The anatomy of one of the most intelligent animals in the ocean

Cuttlefish belong in a scientific group called 'cephalopods' and are related to octopuses and squid. There are about 120 types worldwide, and of those, three can be found in the UK: the common, elegant and pink cuttlefish. Like their relatives, cuttlefish are one of the most intelligent invertebrates.

They are the superheroes of the underwater world, and have so many amazing adaptations to survive in the wild. Cuttlefish are born with these abilities as soon as they hatch from the pure-black, grape-like eggs they were laid in. These sea grapes, as they are also known, can wash onto the shore after they are dislodged from the marine plants they were attached to following stormy weather. You can also find their internal floats, called cuttlebones, that wash up after they die, soon after mating.

When the young cuttlefish come out of their eggs, they are the size of a fingernail, and they will start to hunt immediately. They themselves are hunted by dolphins, other cuttlefish, fish, sharks and seabirds. But they have clever tricks to escape being eaten.

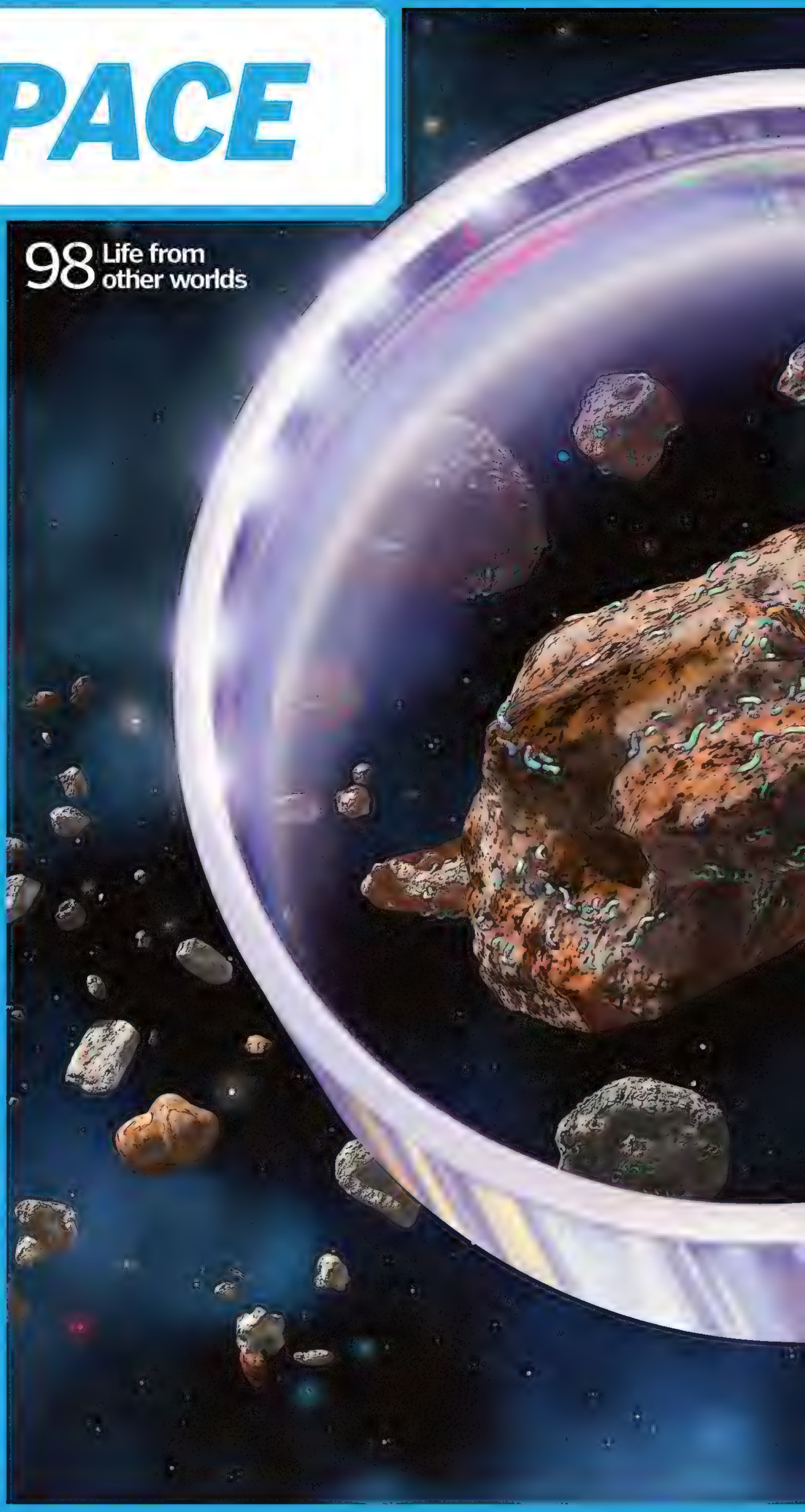
Cuttlefish generally move quite slowly through the water... until they are spooked. Then they transform into a torpedo, darting backwards and quickly squirting out a cloud of black ink that is stored internally in an ink sac. This confuses their predator, leaving the cuttlefish to skulk away and further impress on their camouflaging skills.


A group of common cuttlefish swimming through the seaweed

© Getty

Masters of disguise

SPACE



AR ZONE!

BACK TO THE MOON

NASA'S BIGGEST MISSION IN OVER 50 YEARS WILL PUT BOOTS BACK ON THE MOON AND BRING US ONE STEP CLOSER TO MARS

Ailsa Harvey

The Moon has captured the attention of humans for as long as we have gazed upon the stars. Reflecting the Sun's light into each dark night, its presence reminds us of the worlds beyond our own. But explorers in the form of astronauts have done much more than simply look upon it.

On 20 July 1969 the first humans landed on the Moon. As part of a series of missions dubbed the Apollo program, NASA astronauts returned to Earth with more knowledge of the rocky orb than our species had ever acquired before. But to think that a handful of missions to this world could make us experts of this foreign terrain would be a mistake. We have only explored a tiny portion of the Moon, and there is still so much more to learn.

It has been just under half a century since we last visited the Moon, and NASA has now revealed its plans to place the next astronauts on its surface by 2024. At least two more people will follow in the few dusty footsteps of the Apollo program's moonwalkers.

When the Apollo program was launched, we knew few details about the silvery sphere that graces our skies. Upon the astronauts' successful return to Earth with samples from the Moon, we were able to learn the majority of what we know today about our planet's natural satellite. We learned that the surface of the Moon has a dust covering and the structure contains a core, mantle and crust just like Earth's. For Apollo, putting humans on the Moon was the main and final goal. It provided us with a better understanding of what was previously an uncharted and unimaginable environment. Soon this territory is to be further explored, and humanity's achievements in space travel to be expanded upon.

> *"A prime goal is to send the first woman to the Moon"*

Apollo's successor is Artemis – a program aptly named after the mythological Greek goddess of the Moon: Artemis is the twin sister of Apollo. While the Apollo missions were executed solely by men, a prime goal of Artemis is to send the first woman to the Moon. In keeping with the theme, the vehicle that will carry the next astronauts to the Moon is a capsule called Orion, the name of the goddess Artemis' hunting partner. Successfully placing a female astronaut on the farthest place we've been from Earth will be an important step for the global space industry.

Perhaps the most ambitious of the Artemis mission's objectives involves using the 2024 Moon landings as a stepping stone to a mission to Mars. This is a planet that scientists believe could have once been home to life – or may still be hosting it. Robots have done all the detective work on Mars so far, but NASA now aims to send astronauts there by the 2030s.

With a future exploration target set on the Red Planet, the return to the Moon will be used to provide us with the knowledge and tools to better navigate our Solar System. But how exactly can the Moon help prepare us for a mission to Mars, an entirely different and more

The US won the Space Race by landing on the Moon first

© Getty

AR ZONE! SCAN HERE

THREE-PART PLAN

2021
Artemis I

The first mission will be uncrewed to test the safety of takeoff, the capsule's ability to travel around the Moon, descent and splashdown. The rocket will also carry 13 small satellites into deep space to perform experiments and technology demonstrations. For six days the spacecraft will orbit the Moon, collecting data about its performance.

2023
Artemis II

Carrying the first four Artemis astronauts, the Orion capsule will take the crew further than humans have ever travelled before in space. Over the approximate ten-day mission, the crew will complete a lunar flyby and return to Earth, evaluating the spacecraft's systems while carrying humans.

2024
Artemis III

This is the mission that will see the next man and first woman step onto the lunar surface. Providing previous missions have been successful, the astronauts will shoot towards the Moon, using the lunar lander to lower two people to the Moon's south polar region. They will remain on the Moon for around a week.

unpredictable mission? Part of this logic is to maintain a gradual progression towards Mars, ensuring that astronauts are as experienced as they can be.

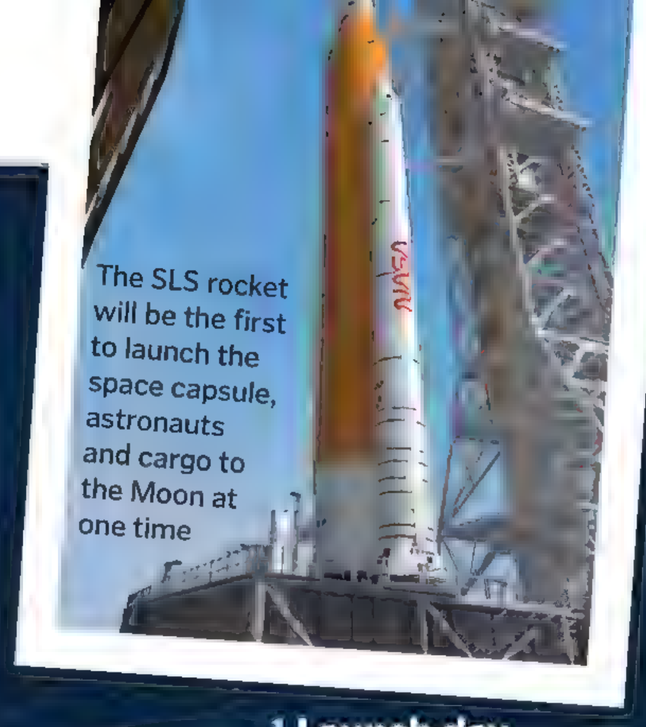
Humans have evolved to thrive on Earth, and they can't survive by themselves outside its atmosphere. In order to cheat nature and explore space, astronauts rely on science and technology, with NASA planning and preparing extensively. Much of what we know about how the human body reacts to low gravity, the hostility of outer space and how humans can survive in space comes from ongoing experiments on the International Space Station (ISS).

Living 400 kilometres above our planet's surface is unimaginable to most of us, but a two-day journey to the ISS from Earth is nothing compared to the months it would take to travel to Mars. The Moon is a stepping stone – in both time and distance – towards the Martian dream..

The Artemis plans are well underway, and the first three missions are likely to be the catalyst for many more. Although NASA's sharpest minds will have the trip meticulously calculated, exactly what the astronauts will find remains to be seen. As the mission draws closer, a recent discovery has added significance to this ambitious plan. A NASA aircraft, called the Stratospheric Observatory for Infrared Astronomy (SOFIA), discovered that the Moon has a higher abundance of water than previously anticipated and across a much greater area. The water was found on a sunlit surface of the Moon, meaning any available water isn't limited to the coldest, darkest regions, as previously suggested. There could be more of this life-supporting resource trapped within the lunar surface for Artemis explorers to utilise. If this vital resource can be spotted using distant telescopes, time will only tell what we will learn when the Moon is back beneath our feet.

EARTH TO MOON

Jump on board the Orion as we follow the route planned for the Artemis astronauts



The SLS rocket will be the first to launch the space capsule, astronauts and cargo to the Moon at one time

1 Launch day
Scheduled to launch in October 2024, the third Artemis mission and second with crew on board will takeoff from the Kennedy Space Center in Florida. Around five kilometres away from the launch pad, the action will be watched and monitored by the Launch Control Center.

4 To deep space
Set on a carefully formulated trajectory, the astronauts will travel over 384,000 kilometres. This trajectory needs to account for factors such as the pull of gravity and the movement of the Moon. The uncrewed Artemis I mission will be able to test the planned path.

3 Trans-lunar injection
Having successfully made it into Earth's orbit, the Orion vehicle is ready to cross over to the Moon. During a 20-minute burn, the engines fire to increase the speed of travel, displacing the spacecraft from its low orbit.

9 Splashdown
After less than 30 days in space, the parachuted capsule will land on Earth, its fall cushioned by the Pacific Ocean. NASA will have a team ready to retrieve the crew and the capsule

NASA tests exit procedures from an Orion spacecraft

Artist's concept of an Artemis lunar lander leaving Earth's orbit

- To the Moon
- Return to Earth
- Gateway orbit

2 Entering orbit
Once the rocket has completed its task of taking Orion into orbit, its engines shut down and it will separate from the crew's capsule. These rocket components then fall towards the Pacific Ocean. Left to fend for itself, Orion will deploy its solar arrays.

5 Lunar flyby
A main engine burn 185 kilometres above the Moon's surface will put Orion on a trajectory to intercept the orbit of the lunar gateway station.

7 Spacewalk
Before exiting the lander, the astronauts will have changed into their extravehicular spacesuits. These will allow them to spend many hours patrolling the Moon, collecting samples and conducting experiments. They are likely to explore Shackleton crater at the south pole and will remain on the Moon for roughly seven days. As an area where water ice is present, astronauts will explore the suitability of the area for a permanent moonbase.

© NASA/Jason Robens

The first woman on the Moon will take her first step on unexplored territory

6 Moon landing
Having docked with the Gateway, which will be orbiting the Moon, the crew may need to inspect the station and collect any supplies they might need. While two astronauts will stay aboard the spacecraft in orbit, the other two will then change over into a lander vehicle. This will take them on the relatively short descent down onto the Moon's southern surface.

© NASA

8 Ascent
Having carried out the planned experiments on the Moon, the astronauts will reboard the Human Landing System and return to their crew on the Gateway. Taking any essential samples back to Earth with them, they will return to Orion to make the journey back home.

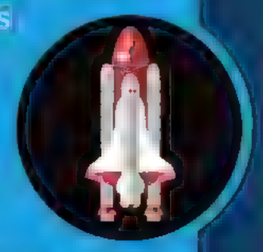
MAIN MISSION OBJECTIVES

Long-term presence
Following Apollo 17's three-day presence on the Moon, Artemis will send astronauts there for weeks at a time.

Equality
A female astronaut hasn't set foot on the Moon yet, and this mission will demonstrate the increasing role women have played in space missions since the Apollo era.

Partnerships
NASA has collaborated with private companies such as SpaceX and Boeing. These partnerships show space travel's shift towards commercialisation.

Technology
NASA is always learning from past missions; the spacecraft and astronauts' suits have been tailored to the Moon mission to exhibit the latest in space technology.



Knowledge
Collecting further information about the lunar surface and deep space, NASA hopes to become better prepared for later missions back to the Moon and further afield.

Resources
Access to the lunar surface provides the opportunity to search for rare mineral deposits and exploit resources. Depending on their abundance, any hydrogen and oxygen could be used as rocket fuel to travel from the Moon.

AR ZONE!

CHECK THE TECH

From the astronauts' suits to a Moon-orbiting station, how will the latest technology assist the Moon missions?

Launch

The launch rocket is responsible for the all-important task of firing the capsule and crew into space. The Space Launch System (SLS) is NASA's new rocket designed for human space travel beyond Earth's orbit. Having to travel almost 1,000-times farther than those headed for the ISS, it is designed to reach speeds of 40,000 kilometres per hour. Approximately eight minutes after launch, the core stage falls away and the astronauts can continue with their journey to the Moon.

Launch vehicle stage adapter
The nine-metre-tall cone-shaped structure connects the core stage of the rocket to the upper stage and crew capsule. It also acts as a protective shield for the engine in the upper stage.

Solid rocket booster
These provide 75 per cent of the rocket's thrust during launch. After the initial ascent, the boosters separate from the SLS and fall back to Earth.

RS-25 engines
Four liquid hydrogen and liquid oxygen-fuelled engines are evenly distributed in a square pattern to add stability, as they produce nearly 9 million newtons of force. It takes five seconds for the engines to reach 100 per cent power.

Core stage
65 metres tall and some eight metres wide, the largest area of the rocket stores the engine fuel, as well as the flight computers needed to control the rocket.

Crew module
The astronauts' capsule is situated near the top of the rocket, allowing modules to safely detach below them.

Travel technology

The Orion spacecraft that will deliver astronauts to the Moon is designed to have the lowest mass possible, while still being strong enough to withstand the conditions of space. This will enable the capsule to carry the astronauts and their equipment using minimal fuel.

Habitat
The capsule is designed to accommodate up to four people. However, space is tight as the compact spacecraft needs to fit safely at the top of the rocket.

Metallic coating
The crew capsule is designed to control heat, keeping temperatures from soaring when exposed to the Sun, but retaining heat when in the cold void of deep space.

Solar power
When in space, four solar arrays open from the spacecraft. Converting energy from the Sun, they provide the service module with enough energy to power two three-bedroom houses.

Service module
Providing life support to the astronauts, this section releases oxygen and water into the crew module. After separation from the rocket, this section holds the energy to transport the capsule through space.

Launch abort system
Coming into play if a problem arises, the top of the rocket has a motor that will pull the Orion spacecraft away from the rest of the rocket for a safe landing.

Space Launch System (SLS)

What makes this NASA's most powerful propulsion system?

AR ZONE! SCAN HERE

Gateway to the Moon

For exploration of another celestial body, astronauts need a station to call base camp. The Lunar Gateway will serve this purpose. Orbiting the Moon, Orion will be launched to synchronise with the path of this station. When the spacecraft reaches the Gateway it will dock, and the astronauts can leave Orion.

Serving a similar purpose to the ISS – but travelling in a completely different orbit – the Gateway is a place where astronauts can conduct science experiments and prepare for the main stage of their mission – the landing. Unlike the ISS, however, the Lunar Gateway will house astronauts for shorter periods, and won't be permanently occupied. Built with return trips to the Moon beyond the initial Artemis missions and long-term human presence in mind, this component will become vital for deep-space exploration.

This image shows how the Orion spacecraft will dock with the Gateway

The Human Landing System will allow vehicles to descend and ascend from the Moon

Moon landing

Transporting the astronauts to their lunar destination is the Human Landing System. This vehicle is designed with a pressurised crew cabin to dwell inside before stepping out onto the surface of the Moon. The companies working on the human lunar landers include Blue Origin, SpaceX and Dynetics. To safely make it onto the lunar surface, the vehicle will need to achieve a slow, soft landing.

Moonwalk

If we want to send astronauts to the Moon, they will need the latest technology to assist them. While astronauts have undergone multiple spacewalks since the Apollo missions, these have not required them to walk on the surface of a celestial body. The next astronaut to walk on the Moon will do so in a brand-new, updated spacesuit.

NASA has unveiled Artemis-generation spacesuits designed especially for the mission: one for the launch and landing, worn inside the spacecraft, and one to protect the bodies of those venturing outside the protection of the Orion capsule. The suits will be custom fit to their bodies with the aim of improving upon the comfort and practicality of previous versions of suits.

xEMU
Short for Exploration Extravehicular Mobility Unit, this is the suit designed for exploring the lunar surface.

PLSS
The updated Portable Life Support System is a backpack which supplies the astronaut with oxygen, pressure regulators to monitor pressure inside the suit and cooling systems. It lasts longer than previous versions to accommodate extended exploration.

Orion Crew Survival Suit
This lighter suit is for use inside the spacecraft between takeoff and landing.

Helmet
This headpiece is designed to be lighter, stronger and have better noise reduction.

Free rotation
Spacesuit joints at the waist and shoulders allow full rotation, increasing manoeuvrability.

High visibility
The bright-orange colour allows astronauts to be clearly seen should they need to exit the spacecraft in an emergency.

One-piece
Unlike previous spacesuits, the torso and legs are one connected piece. The astronaut enters from the top.

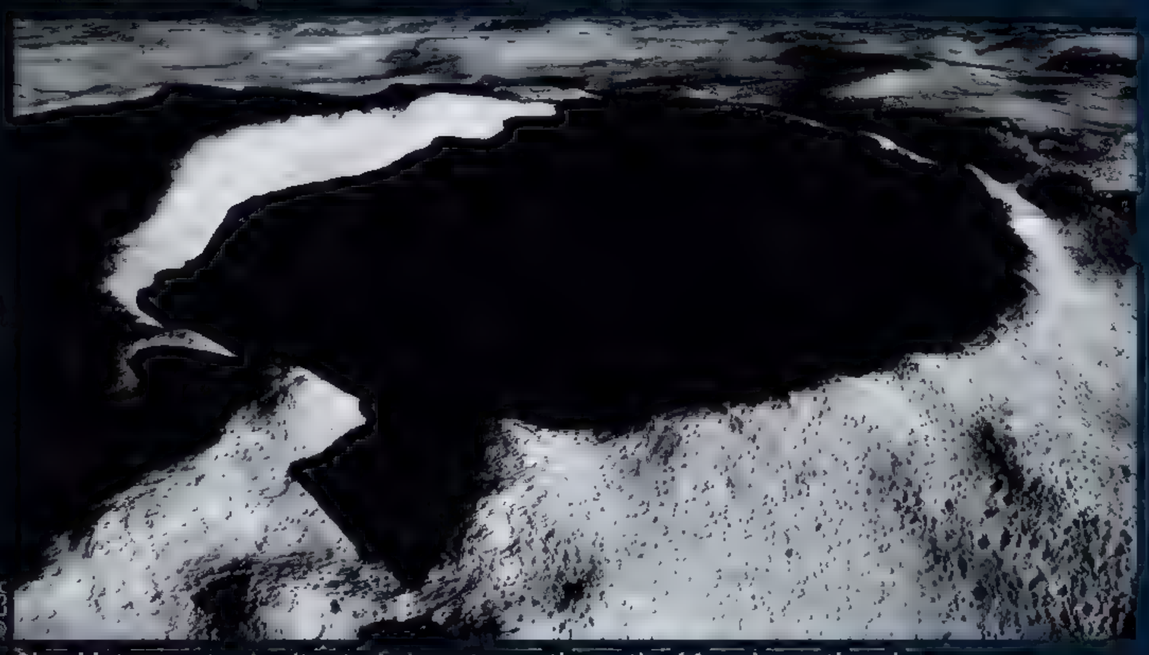
Improved mobility
Apollo astronauts had to hop on the Moon to move, but this suit will allow bending of the legs to walk and kneel more easily when conducting experimental work.

Where are we going?

For the initial Artemis Moon missions, the selected astronauts will likely fly to the Moon's south pole. This area has great potential as it is believed to be home to the highest abundance of water ice. If we can extract this water, it could be used to sustain human exploration farther into space, whether that's a human hydration source, rocket fuel resource or cooling system for equipment.

Shackleton crater is a huge 19-kilometre-wide depression in the Moon's surface and a feature well worth visiting. With a permanent shadow cast in the dips of the crater, the low temperatures make it a promising location for ice to form.

In fact, these permanently lightless areas maintain some of the coldest temperatures in the entire Solar System. Although it's possible that water can be found even on the Moon's lit surfaces, an area likely to have the highest abundance of water is the best spot to start looking for further natural resources.



© ESA

Shackleton crater is situated almost exactly on the Moon's south pole

First woman

Between 1969 and 1972, six missions took place in which 12 people stood on the surface of the Moon – all of them men. For such a high-risk mission, the most experienced astronauts were required, and at the time there were no women at NASA who had suitable test flight experience.

For a long time space was viewed as an industry primarily for men, and it wasn't until 1978 that NASA selected its first female astronauts. Today, 65 women have been to space, and this mission will serve as a reminder of changing times.

While it's currently undecided who will be chosen, it will be one of NASA's astronauts who has already worked aboard the International Space Station. The team of astronauts is expected to be announced at least two years prior to the mission launch.

The first class of astronauts to graduate under the Artemis program includes six women

© NASA

Steven Swanson (left) prepares for the Soyuz TMA-12M launch with Aleksandr Skvortsov (middle) and Oleg Artemyev (right)

Swanson has performed 27 hours and 38 minutes of extravehicular activity

© NASA

Q&A STEVEN SWANSON

The three-time NASA astronaut tells us about life in space and the significance of Artemis

During his career at NASA, Swanson logged over 195 days in space, undertaking five spacewalks. His three missions to the ISS include two Space Shuttle flights (STS-117 and STS-119) and one Soyuz flight (TMA-12M).

How does NASA select astronauts?
Nobody knows for sure. Really it's up to the chief of the astronaut office to make that selection, and sometimes others depending on how high profile the mission is. But it's partly just where you are in the queue, because we come in as a group together. The people who came in the group before will fly before you do. I didn't think about an astronaut career until I was about 25. It took 12 years from that point to become one, and I ended up working 11 of those years at NASA as an engineer.

What's it like to spend significant time away from Earth?
I spent about six months in space, and it's not tremendously difficult. Family and friends is the first thing you miss, but we could Skype and the communication with our families was good. You can get down periods, when you get a little tired of it – you haven't really gone outside and the food gets old after a while.

"Family and friends is the first thing you miss"

How do you prepare for a spacewalk on Earth?
We have a big pool that we train in, with mock-ups of the outside of the International Space Station. Divers weigh us out to the point where we don't float up or down. We just stay floating right there in the water with all of the tools that we would have in space, and we learn how to move in this environment. You go through all the protocols over and over again, and it's a long training day. You do those six hours in the water uninterrupted and then a couple hours before and after for briefs and things. It's really worthwhile and helps tremendously for when you do the real spacewalk.

How much have the spacesuits improved for Artemis?
The biggest difference is in the shoulders. You get the ability to really reach around and have more movement, like you would without a suit on. They also have better mobility on the legs. On the International Space Station you didn't really use your legs much for anything, so it didn't matter how much mobility you had in your lower body. Now it's going to matter tremendously on the Moon, so they've modified the lower part to be more moveable.

What changes can the Artemis crew expect in their bodies?
The first thing we have to worry about is muscle and bone loss. Astronauts now work out two hours a day, so we do a pretty good job of mitigating that, but we still see some muscle loss. Bone loss is pretty much covered now. I only had one per cent bone loss from six months on board, and that was a good number. That comes back after about a year.

In our experiments while we were up there, we found that 30 to 40 per cent of the astronauts are getting major changes in their vision, and we haven't figured out exactly why. That's an ongoing process right now. There's just many things that change while you're up there. We've known for a while that the immune system gets degraded, so we're very careful about being quarantined before we go so nobody takes any germs or bugs with them on the way up. You don't want to get sick up there.

What's it like travelling in a space capsule?
Between the Soyuz and the Shuttle, the Soyuz was much smaller. The Orion is not as tight as the Soyuz, so they'll have a little more room, but it still won't be as roomy as the Shuttle. You don't have a lot of room to stretch out and move around in a capsule, but you're usually pretty busy during that time frame making sure all systems are working well. It's mainly a process of keeping the vehicle going to explore this destination correctly and keeping the vehicle safe.

How significant do you think the Artemis program is?
The real goal is Mars. And we will use the Moon as a test bed because Mars is a very difficult mission. It's going to take almost three years, and you can't come home early on a Mars mission. It's a seven- or eight-month journey to get there and you have to wait 15 months there for the planets to align correctly again before you return. It has to be very well thought out and the best way to do that is on the Moon.

As well as Mars, we can also use the Moon as a test bed for other things – to see how we can actually gather materials from the Moon itself and maybe use that to make our fuel.

Swanson was first selected as a NASA astronaut in 1998

SpaceX Dragon capsule

The first-ever commercial spacecraft to leave and return to Earth explained

When the NASA Space Shuttle was retired in 2011, several companies competed to become NASA's new choice for cargo and crew transportation to the International Space Station (ISS) – and possibly beyond.

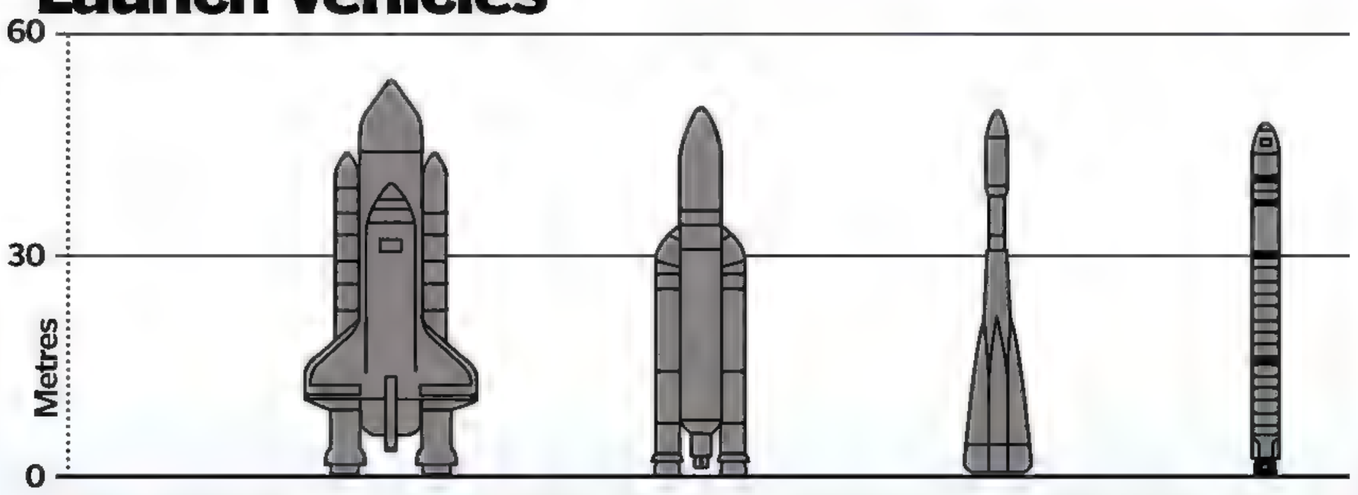
In 2006 and 2008 NASA awarded the private company SpaceX two contracts totalling roughly $2 billion (£1.59 billion), paving the way for the Dragon capsule to complete its first successful orbit and re-entry in December 2010.

Powered by a combination of solar panels and an advanced lithium battery, the Dragon capsule is large, allowing for the transportation of up to seven crew members or up to six tonnes of cargo. It uses 18 liquid-fuel thrusters equipped with dinitrogen tetroxide and monomethylhydrazine to manoeuvre while in orbit. Like NASA's Orion, the conical shape of the Dragon capsule is deemed the best for Earth re-entry, while also allowing for a sizeable interior.

One of its defining features is a variant of NASA's Phenolic-Impregnated Carbon Ablator (PICA) heat shield. SpaceX's PICA-X heat shield advances on NASA's design in a number of places, notably its significantly reduced cost and added reusability. This allows it to be used hundreds of times, whereas NASA's currently does not survive its flight. This shield protects the capsule as it re-enters Earth's atmosphere at several thousand degrees and keeps the interior close to room temperature.

Three oversized parachutes slow its descent to Earth, although it can operate on only one if the other two should fail. The capsule has to land in water. The last flight of Dragon's first iteration touched down in the Atlantic Ocean off the coast of Florida after ferrying supplies to the ISS on 7 March 2020. Resupply missions – as well as missions delivering crew – will now be taken over by Dragon 2.

Launch vehicles



	Space Shuttle	Ariane 5	Soyuz	Falcon 9
Origin	US	Europe	Russia	US
Cargo to ISS	16.1 tonnes	16 tonnes	8.2 tonnes	22.8 tonnes

Inside the Dragon capsule

Launch abort
Unlike NASA's Orion spacecraft, which uses a rocket to 'pull' the capsule off in an emergency, the Dragon uses its lower boosters to 'push' the capsule off the launch pad if required.

Nose cone
This protects the spacecraft during launch and before the separation stage, and also contains the mechanism for docking with the ISS.

Parachutes
Three parachutes, each 35 metres in diameter, deploy at 3,000 metres and slow the spacecraft's descent to about five metres per second.

Heat shield
Advancements in technology allow the PICA-X heat shield to be reusable. This provides protection from the heat when entering Earth's atmosphere.

Service cabin
This section contains the thrusters, fuel and parachutes, remaining attached to the spacecraft for the duration of the mission.

Solar panels

Trunk
Allows for the storage of unpressurised cargo such as small deployable satellites. Also contains the solar panels, and is jettisoned before Earth re-entry.

Pressurised cabin
Equipped with hatches and windows, this section provides protection against radiation and micrometeorites for crew and cargo.

Draco thrusters
These provide precise control of the spacecraft, enabling safe docking with the ISS and a return to Earth within a few hundred metres of a target.

The statistics

SpaceX Dragon capsule

Height: 4.4 metres

Diameter: 3.66 metres

Launch mass: 6,000 kilograms

Re-entry mass: 3,000 kilograms

Top speed: 27,000 kilometres per hour

Flight time:
One week to two years

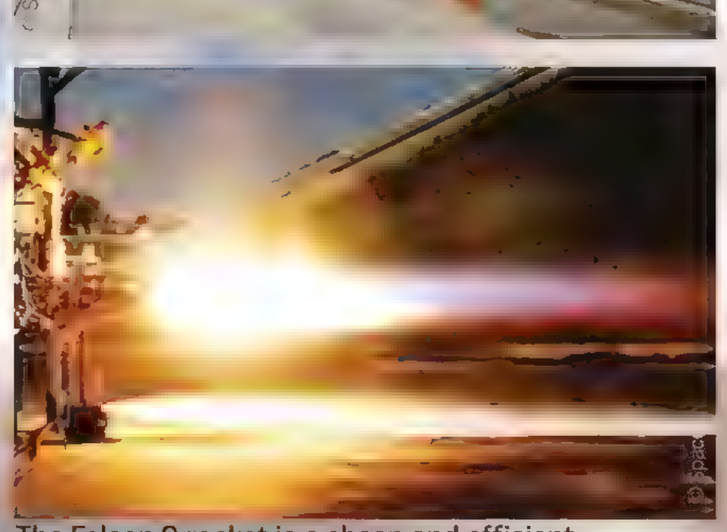
Falcon 9

SpaceX's Falcon 9 rocket is responsible for taking the Dragon capsule into orbit. Developed from the ground up by SpaceX for cost-efficient transport into orbit, the Falcon 9 is a two-stage launch vehicle that uses liquid oxygen and rocket-grade kerosene. Its aluminium-lithium alloy exterior uses the strongest and most reliable welding techniques available.

The Falcon 9 first-stage is powered by nine Merlin engines, which are the highest performing American hydrocarbon rockets ever flown. The engines generates over 1 million pounds of thrust in a vacuum, employing the same technology as that used in the Apollo Moon missions.

In line with the company's goal of reusability, SpaceX has managed to make the first stage reusable, with it able to return to a drone ship after launching a payload. The second stage, which separates from the Dragon capsule and falls to Earth at a much higher altitude, will require significant advances in heat-shield technology to withstand atmospheric temperatures and become reusable.

Elon Musk, founder and CEO of SpaceX, with the impressive Falcon 9



The Falcon 9 rocket is a cheap and efficient solution for space travel

Life from other worlds

Could life have been brought to Earth by meteorites, space dust or even aliens?

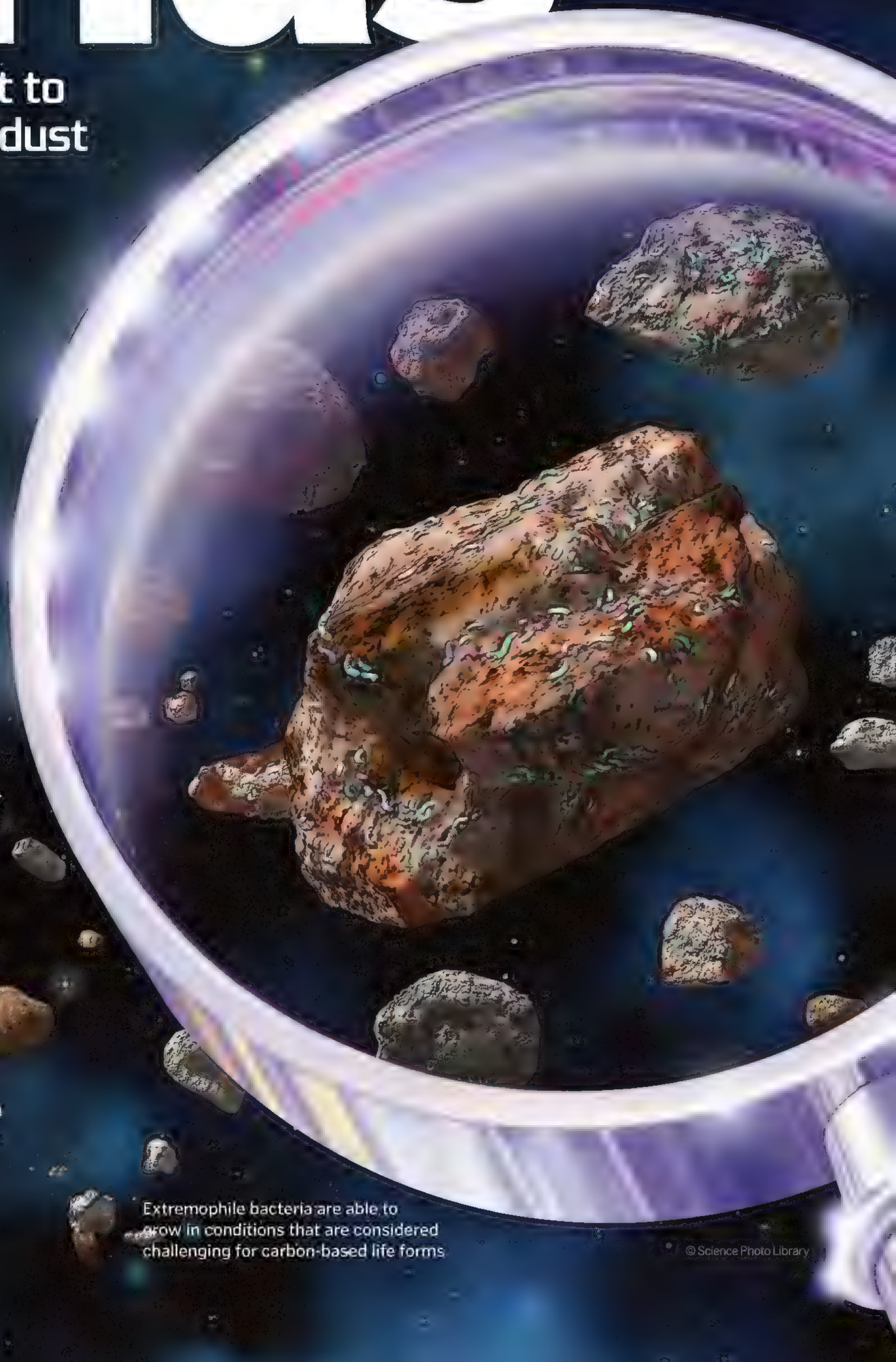
Words by **Ailsa Harvey**

How life originated on Earth is one of the most fundamental problems ever to puzzle scientists. The world we know is teeming with remarkable species. It's the existence of these living things that separates our planet from all the other worlds we've discovered and explored. Earth's ability to support life has created diverse ecosystems and brought us all into existence. But its origin happens to be one of the longest standing debates in scientific history.

Panspermia is the name of one popular theory, stating that life isn't confined to just one planet. It didn't necessarily originate on Earth, and it can be transported and spread throughout space. Although the theory involves some wild claims that border on science fiction, others are based on fragments of solid scientific evidence.

The most plausible of this theory's explanations for the interplanetary distribution of life, is that bacterial colonies were transported from one planet to the next. Evidence of microbial life within meteorites on Earth may indicate that this transportation was made possible by material dislodged from other bodies that then travelled on its own trajectory through space. If this is the case, is our world a one-off, produced by chance, or could microbes have created a series of Earth-like homes on numerous planets throughout the universe?

Some versions of the panspermia theory are becoming closer to being either proven or dismissed. As we explore the universe that surrounds our home planet, our evolving knowledge and technology are allowing us to venture farther afield and investigate more thoroughly. In some instances, signs of life are being detected on planets that we once thought were lifeless. But it's only when we understand the definition of life more thoroughly that we can begin to truly understand where it came from, along with our own existence.



Extremophile bacteria are able to grow in conditions that are considered challenging for carbon-based life forms

5 signs of life beyond Earth

1 Viking lander experiments

In 1976, NASA's Viking landers began their trawl of Mars, hunting for signs of life. During one of the experiments, the landers detected chemical activity in the soil that indicated methane production – a potential biosignature. They also found the five elements essential for life on Earth.

2 Determining probability

A study in 2001 estimated that there are hundreds of thousands of life-bearing planets in the galaxy and that the nearest Earth-like planet could exist just a few hundred light years away. This probability can be calculated by analysing the number of possible life-supporting planets and applying this calculation to unexplored regions. Spacecraft such as NASA's Kepler show that around one-fifth of stars have habitable zones where temperatures could support life.

3 Alien potential

Scientists have been scanning space for alien transmissions for the last 60 years, occasionally detecting unexplained signals. In 2020, astronomers recorded mysterious radio signals from the direction of Proxima Centauri, the Sun's closest star. There are two planets known to orbit this star, and one is thought to be temperate and rocky.

4 Sulphur on Europa

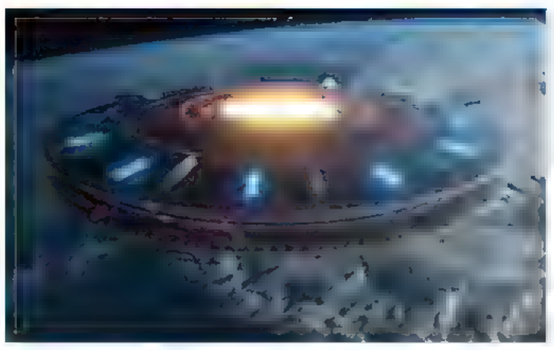
When sulphur traces were found on Jupiter's moon Europa during NASA's Galileo mission, some scientists believed it could be a sign of life there. The sulphur looked like the waste product of bacteria that had risen to the surface. Others believed it had merely come from another of the planet's moons, Io, where sulphur is produced in high volumes by volcanoes.

5 Phosphine on Venus

When the discovery of phosphine gas in the clouds of Venus was announced in September 2020, there was reportedly more than 1,000 times the amount of this gas than found on Earth. Being a rocky planet like Earth, Venus wasn't believed to be able to produce phosphine without life: on Earth, microbes make the gas. Scientists haven't ruled out the possibility that it's produced by a non-living source.

The three variations

What are the main hypotheses for panspermia?



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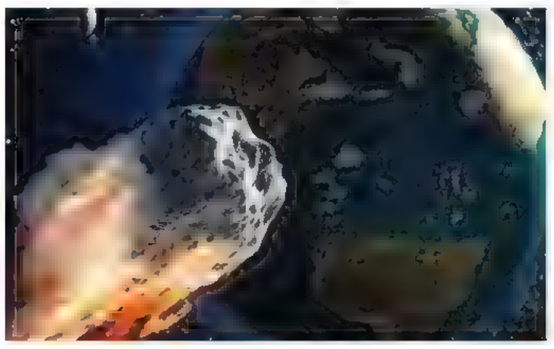
Directed panspermia

Some believe that life didn't just reach Earth from other planets, but was sent here by a more advanced species. Could there be another human-like species out there – or perhaps a more intelligent one – that has created life as we know it?



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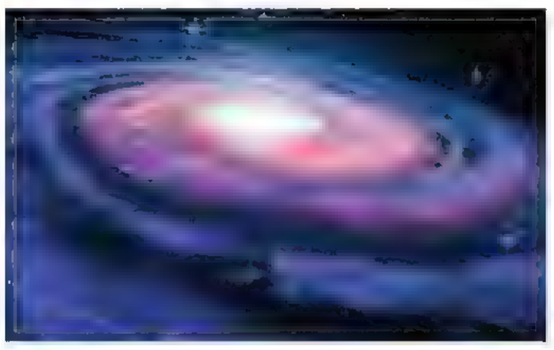
Ballistic panspermia

This theory of interplanetary transfer involves rock from other planets being dislodged and flying through space towards Earth. This specific theory focuses only on planets within our Solar System.



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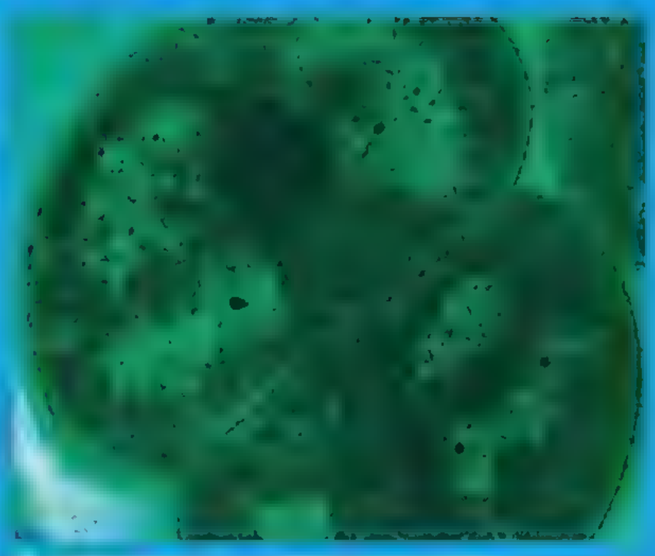
Lithopanspermia

Similar to ballistic panspermia, but looking much further afield, this theory states that the biological matter that developed into life on Earth travelled from beyond our Solar System through interstellar space.

Can bacteria survive in space?



D. radiodurans can withstand radiation dehydration, vacuum exposure and acidity

If life on Earth was seeded from other worlds in the form of bacteria, these microorganisms would need to survive in space for significant periods of time. In May 2015, an experiment was launched by researchers from the University of Tokyo and the Japan Aerospace Exploration Agency, which would prove this was possible for at least one species.

Colonies of *Deinococcus radiodurans* bacteria were placed on the outside of the International Space Station and monitored over the course of three years to see if they would survive. The bottom layer of bacteria returned to Earth alive, having been protected by the dead cells covering them. While not all microorganisms can survive the journey between planets, there is still potential for some. This research has helped to keep the theory of panspermia alive.

AR ZONE!

Could life have come from Mars?

This Martian meteorite holds potential evidence of microbial life on the Red Planet

In 1984, the ALH84001 meteorite was discovered in the Allan Hills region of Antarctica. But it wasn't until 1996 that this lump of rock would gain significance, being used to build upon evidence of panspermia. A group of scientists, led by David McKay from NASA's Johnson Space Flight Center, declared that their research showed signs of Martian life within the meteorite.

At 4 billion years old, this meteorite is thought to have existed on Mars during a period when the planet was abundant in water, an essential resource for life. Scientists looked at the centre of the rock to avoid using sections contaminated by the environment on Earth.

Sceptics fought the evidence, with the view that the patterns and materials within the meteorite could have been formed from non-biological processes. Since then, it's been discovered that minerals from within the rock, such as magnetite, have the potential to be formed from shock waves and not just microbial life. The interpretation of this meteorite is still debated by scientists today, but neither argument can be ruled out as impossible.

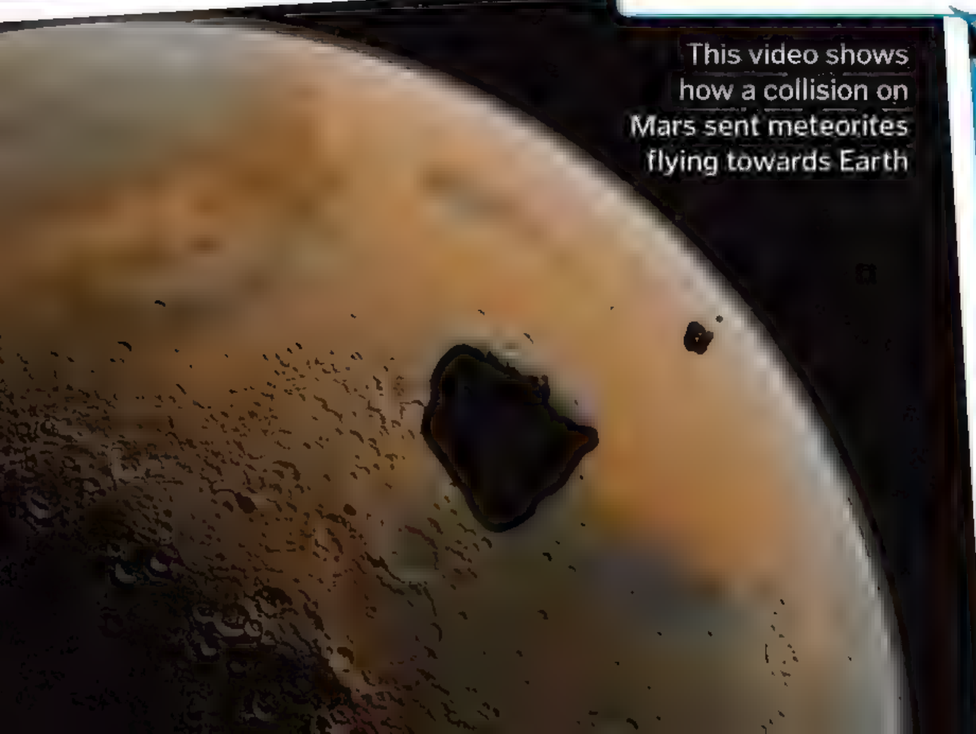
Into orbit
The two-kilogram fragment of Mars would have entered into orbit around the Sun before coming into contact with Earth.

Impact zone
A great impact would have been needed to dislodge the rock from Mars and send it travelling at speeds of over three miles per second in order for it to escape Mars' gravity.

Magma rock
The meteorite is believed to have formed from crystallised magma 4 billion years ago.

© Getty

AR ZONE! SCAN HERE



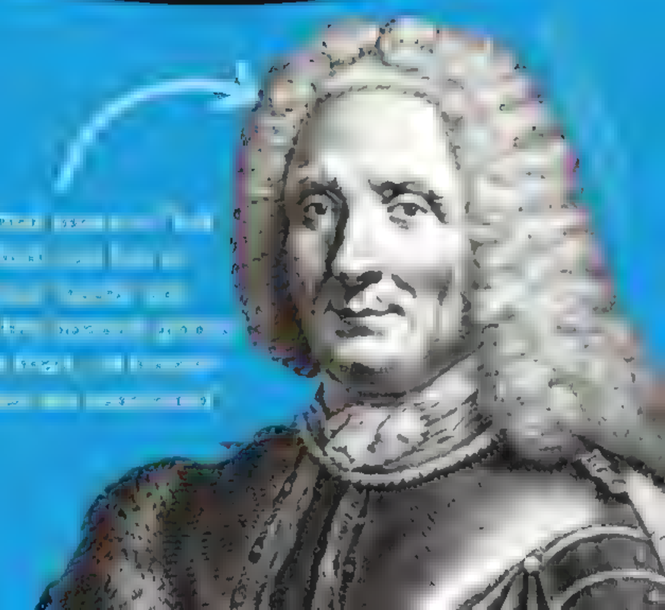
This video shows how a collision on Mars sent meteorites flying towards Earth

Theory development

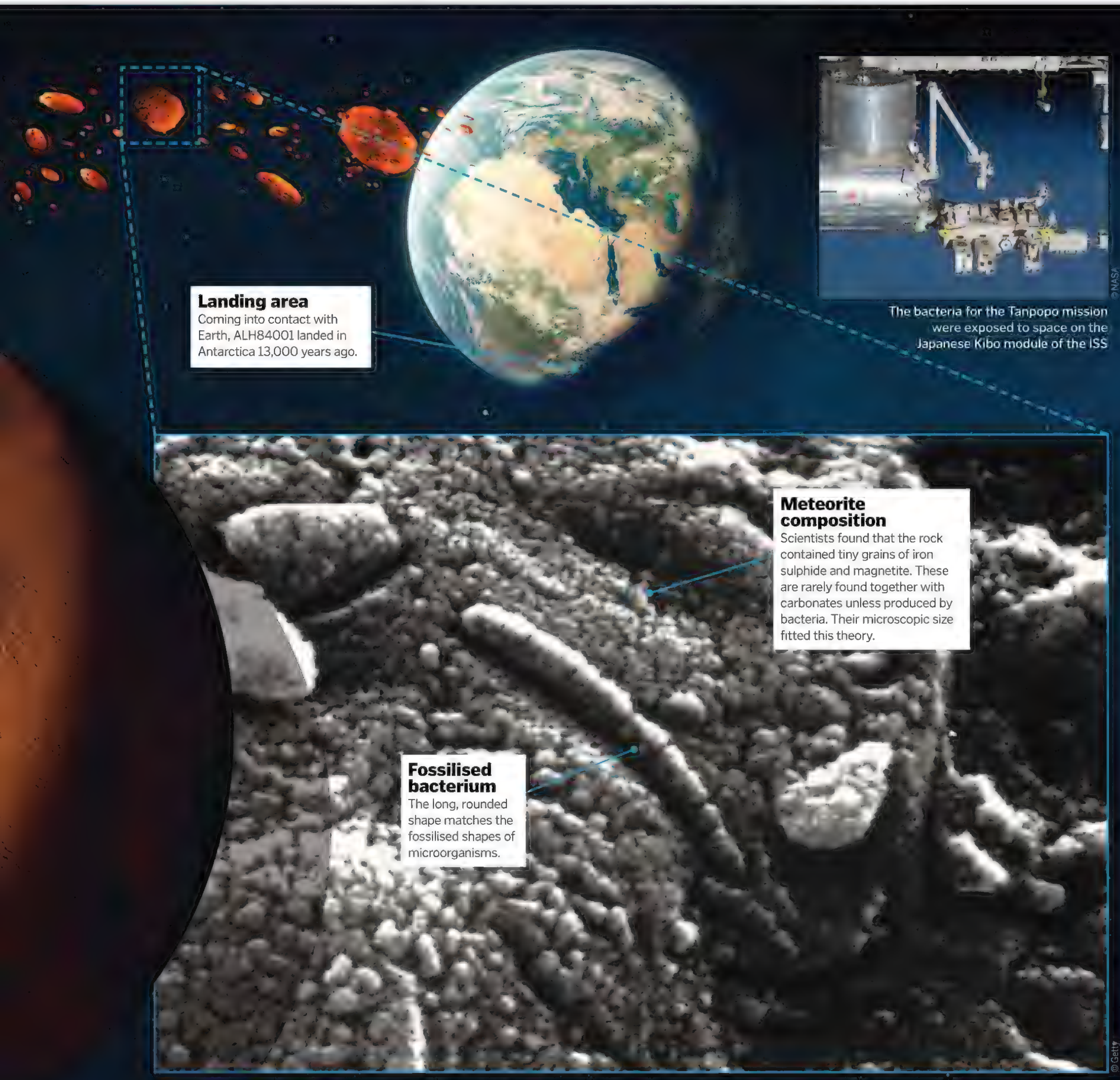
How have philosophers and scientists shaped the evolution of this theory?

500 to 428 BCE

1700s



DID YOU KNOW? *A 0.5-millimetre pellet of Deinococcus bacteria can survive in space for eight years*



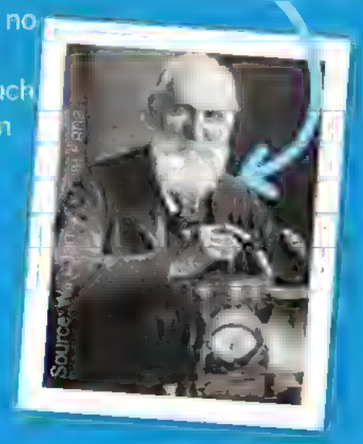
The bacteria for the Tanpopo mission were exposed to space on the Japanese Kibo module of the ISS

1859
Darwin's theory of evolution makes people consider a point of origin for all life. For some, this point is envisaged far from our planet.

1800s
The Kant-Laplace nebular hypothesis emerges, which states that the Solar System was formed from a nebula. If Earth was originally too hot for life, it must have appeared on a previously lifeless planet.

1865
Hermann Richter, a German physician, becomes the first person to define the theory, giving it the name panspermia.

1871
Sir William Thomson claims "there are countless seed-bearing meteoric stones moving about through space. If at the present instance no life existed upon this Earth, one such stone falling upon it might... lead to its becoming covered with vegetation".



1908
Svante Arrhenius, a Nobel Prize-winning Swedish scientist, isn't convinced that life travelled through space on solid objects. Instead he suggests that microbes could be transported through space by solar radiation.

1938
The first fully formed theory of how life could have grown from non-life through chemical evolution on Earth is written by biochemist Alexander Oparin. Many scientists don't consider it plausible, and instead keep the theory of panspermia alive.

How to identify a galaxy

Hubble's 'tuning fork' sorts a bewildering variety of galaxies into a small number of basic types

Astronomers have studied thousands of galaxies, and they all look slightly different. But certain basic features crop up again and again, and these repeating features can be used to classify galaxies into different types. The first person to do this was Edwin Hubble in 1926, soon after it was first established that galaxies are 'island universes' outside our own Milky Way.

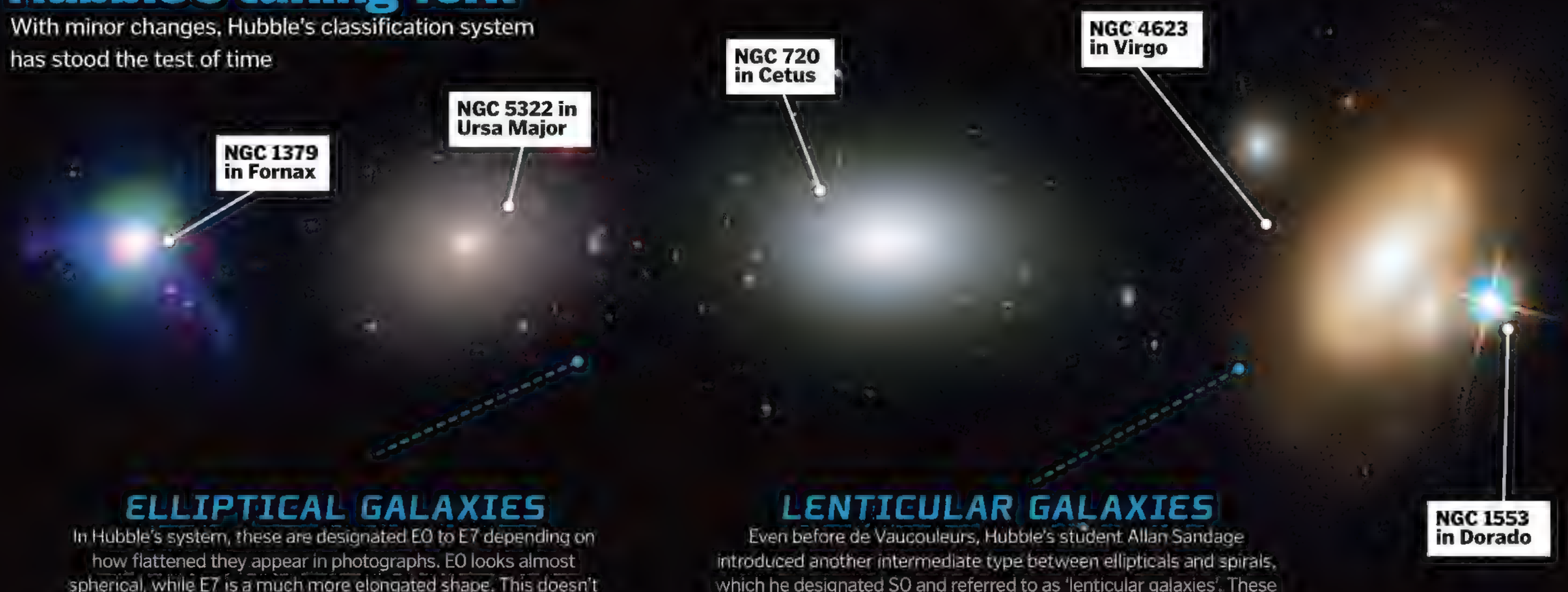
Hubble did this purely on the basis of appearance, so there are many things we know now that Hubble was unaware of. Radio astronomy, for example, has shown us the distribution of otherwise invisible gas, while high-resolution spectroscopic measurements provide information on stellar motions and chemical composition.

Nevertheless, the broad classification system devised by Hubble has survived these new discoveries. As a first cut, galaxies can be divided into two types: elliptical and spiral. Elliptical galaxies are relatively featureless, dominated by old stars that wander round on a random jumble of orbits, with the galaxy as a whole showing little net rotation. Generally ellipticals contain hardly any gas, and as a consequence, very few new stars are formed in them. Spiral galaxies, on the other hand, are full of gas and young stars, with abundant star formation going on in the spiral arms that give them their name. Both the stars and gas tend to move on near-circular orbits in a thin, rapidly rotating disc.

About half of all spiral galaxies show a bar-like structure spanning the central region. Hubble classified these 'barred spirals' in a parallel sequence to the ordinary spirals, giving a characteristic 'tuning fork' shape to his classification system. The same system is still used by astronomers today, often with various tweaks and additions to reflect more recent discoveries.

Hubble's tuning fork

With minor changes, Hubble's classification system has stood the test of time



ELLIPTICAL GALAXIES

In Hubble's system, these are designated E0 to E7 depending on how flattened they appear in photographs. E0 looks almost spherical, while E7 is a much more elongated shape. This doesn't necessarily reflect the galaxy's real shape, though. A cigar-shaped galaxy seen end on, for example, would be classified as E0.

LENTICULAR GALAXIES

Even before de Vaucouleurs, Hubble's student Allan Sandage introduced another intermediate type between ellipticals and spirals, which he designated S0 and referred to as 'lenticular galaxies'. These are disc-shaped like spirals, but they resemble ellipticals in having very little gas or star formation, and lack spiral arms.

Galactic evolution

Hubble referred to ellipticals as 'early type' galaxies and spirals as 'late type'. This is sometimes misinterpreted to mean that he believed there was an evolutionary sequence from elliptical to spiral. He actually meant the opposite. Based on the ages of the stars in them, the ellipticals we see are older – in other words they originated earlier – than spirals. Hubble was implying an evolutionary sequence in which spirals come first and ellipticals later. Although a complete theory of galactic evolution is still lacking, there seems to be some truth to this. Many ellipticals are believed to be the result of two or more spiral galaxies colliding and merging with each other. The initial product may be quite chaotic, but after a while it will settle down to a stable configuration with randomised orbits and less gas – in other words, looking very much like an elliptical galaxy.

NGC 3921 is a merging pair of disc galaxies which may become a single elliptical

Irregular galaxies

One thing all the galaxies in the Hubble sequence – spiral or elliptical – have in common is that they are almost symmetrical in appearance. But some galaxies – as many as a quarter of them – don't fit into this sequence at all. Referred to as irregular galaxies, these tend to be small in size, with around a tenth the mass of our own Milky Way. Irregular galaxies are similar in composition to spirals, with plenty of gas and young stars, but they lack well-defined spiral arms and they are often distinctly asymmetric in shape.

NGC 4449 in Canes Venatici is a nice example of a small irregular galaxy

"The classification system devised by Hubble has survived new discoveries"

SPIRAL AND BARRED SPIRAL GALAXIES

Hubble referred to tightly wound spirals as Sa, less tight spirals as Sb and loose spirals as Sc. Similarly, barred spirals follow a sequence from SBa to SBc. In both cases the size of the central bulge, resembling a tiny elliptical galaxy, decreases along the sequence from a to c.

The Andromeda Galaxy (M31)

Messier 74 in Pisces

The Sombrero Galaxy (M104)

NGC 4314 in Coma Berenices

ANATOMY OF A SPIRAL GALAXY

Spiral galaxies, such as our own Milky Way, have several distinct components

Globular clusters
Many of the stars in the halo are clumped into globular clusters, which look almost like miniature E0 galaxies.

Central bulge
Resembling a scaled-down elliptical, the central bulge is predominantly made up of old stars.

Disc
The most visible part of the galaxy, the disc is dominated by younger stars and regions of ongoing star formation.

Outer halo
The whole galaxy is enveloped by a large, roughly spherical halo, containing relatively faint, very old stars.

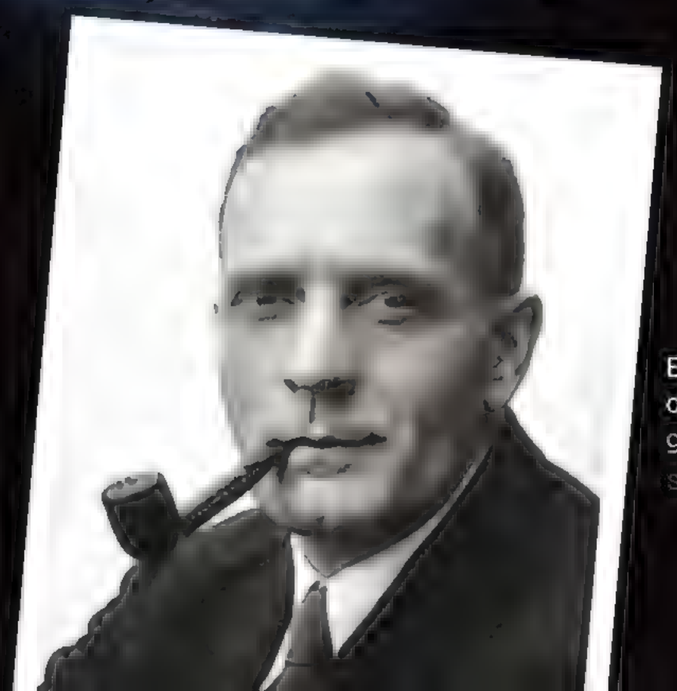
Spiral arms
The characteristic spiral pattern is the disc's most prominent feature, and this is where our Sun is located in the Milky Way.

INTERMEDIATE GALAXIES

Later researchers, such as the French astronomer Gérard de Vaucouleurs, realised that Hubble's tuning fork diagram doesn't do justice to the full variety of galaxy shapes. He developed a more complicated system that introduces an intermediate type between spirals and barred spirals, which he designated SAB.

NGC 1300 in Eridanus

NGC 3079 in Ursa Major



Edwin Hubble, the originator of the 'tuning fork' system of galaxy classification

Source: Wiki/Johan Hagemeyer

HOW SPACE TECH BENEFITS EARTH

Discover some of the inventions made for space exploration that we now use every day

Words by **Scott Dutfield**

The prototype Stanford Research Institute (SRI) mouse from the early 1960s

© SRI International

A computer mouse resembles the tiny mammal, with a cable for a tail

© Getty

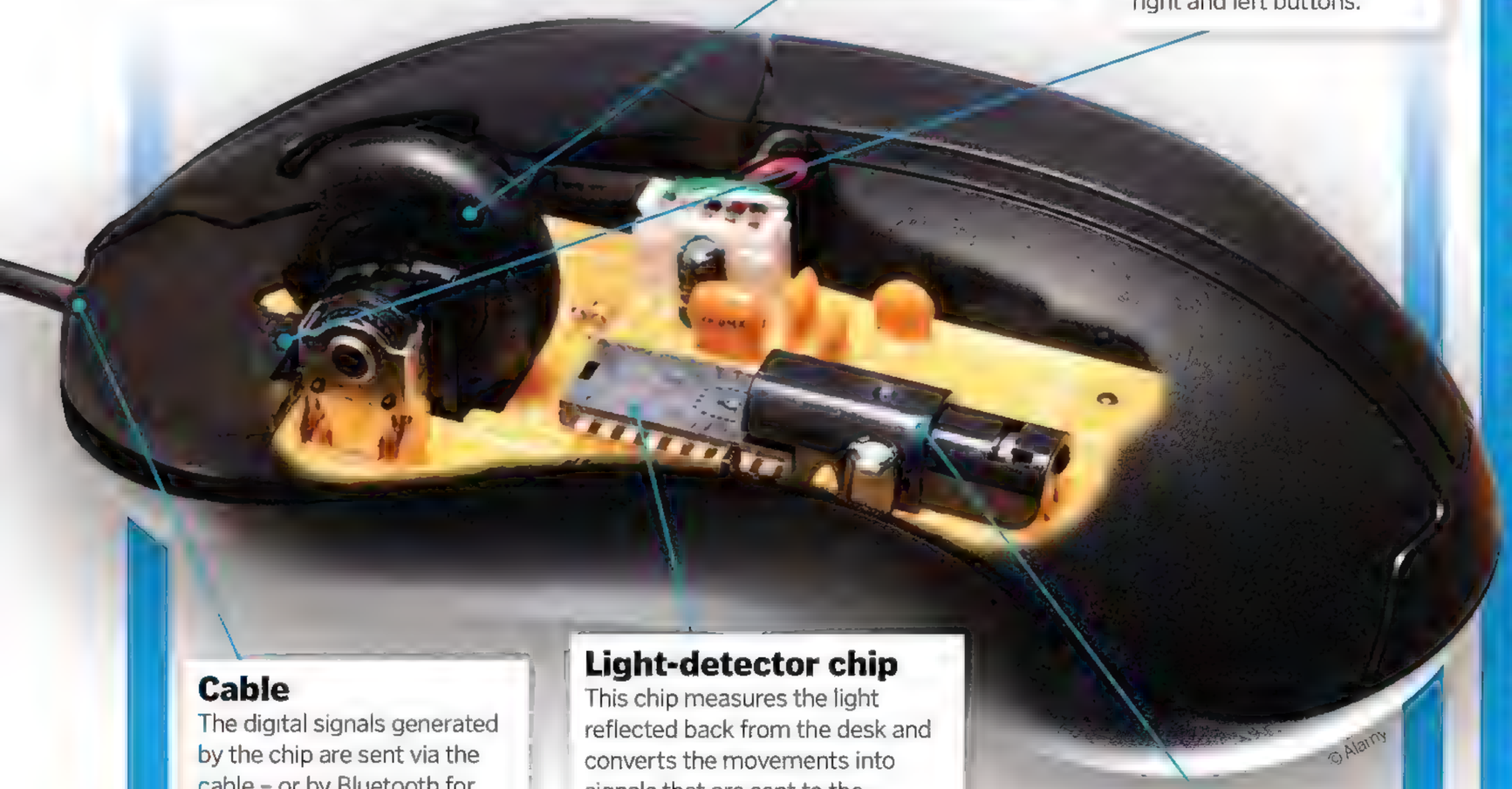
A MOUSE FROM SPACE

When you purchase a desktop computer, a mouse will usually also be included. However, that wasn't always the case. The mouse was created by American engineer Doug Engelbart back in the late 1960s for the Stanford Research Institute. Engelbart's research was funded by NASA, who hoped to make computers, which at the time were being used as flight control systems and for simulations, more interactive. What Engelbart created was a handheld device that used two perpendicular wheels that were turned by pushing the mouse on the flat surface below it. The movement of these wheels would then move the cursor on the computer screen. Engelbart presented the new 'mouse' at the Fall Joint Computer Conference in San Francisco in 1968, where thousands of engineers witnessed it for the first time. Since then the humble mouse has undergone several upgrades, with trackpads and laser tracking becoming the new normal.

"NASA hoped to make computers more interactive"

Inside an optical mouse

How these computer companions move a cursor on the screen



© Alamy

Scroll wheel
This rolling wheel is connected to a switch mechanism that tracks the direction of movement and how much the wheel has rotated.

Microswitches
Two switches either side of the scroll wheel register when you click the mouse's right and left buttons.

Cable
The digital signals generated by the chip are sent via the cable – or by Bluetooth for wireless versions – to the computer to move the cursor.

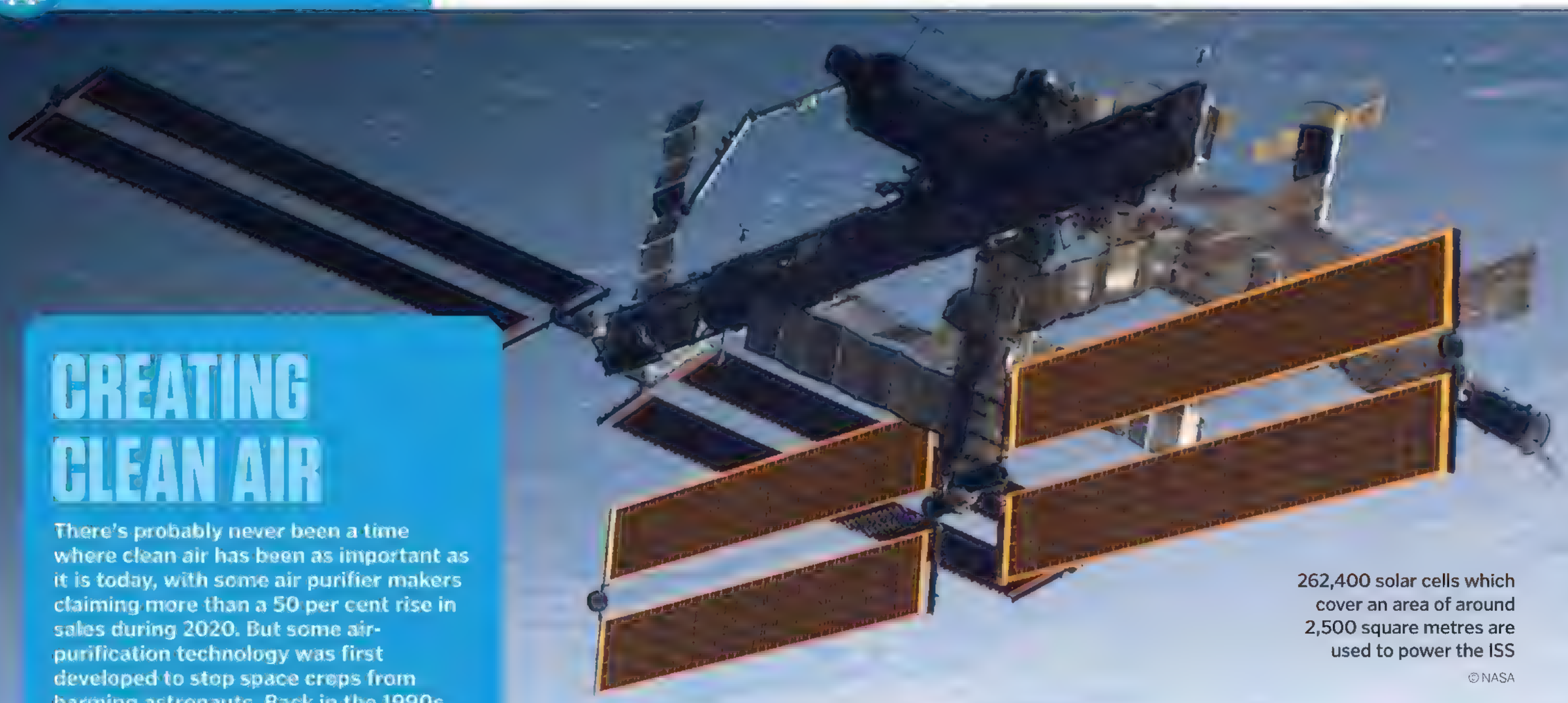
Light-detector chip
This chip measures the light reflected back from the desk and converts the movements into signals that are sent to the computer to move the cursor.

Light
An LED bulb produces the red light which is used to track the movement of the mouse using a detection chip.

SELFIE SCIENCE

It's hard to imagine that mobile phones ever existed without a camera. That was until American physicist Eric Fossum created the pixel image sensor, paving the way for modern-day smartphone cameras and webcams. It was created in NASA's Jet Propulsion Laboratory back in 1993. The intention was to invent cameras small enough for interplanetary space travel. However, Fossum's 'camera on a chip' technology quickly proved valuable for many different industries, including the invention of the camera phone.

The camera in your smartphone evolved from Fossum's original complementary metal-oxide-semiconductor (CMOS) active pixel image sensor. The sensor works using an array of pixel sensors covered by colour filters and a photodiode – a device that converts light into an electrical current. As light passes over the surface of the sensor it is detected and converted into an electrical signal before it is amplified by several transistors. These signals are then interpreted as an image.



262,400 solar cells which cover an area of around 2,500 square metres are used to power the ISS

© NASA

CREATING CLEAN AIR

There's probably never been a time where clean air has been as important as it is today, with some air purifier makers claiming more than a 50 per cent rise in sales during 2020. But some air-purification technology was first developed to stop space crops from harming astronauts. Back in the 1990s, NASA conducted research into removing the build-up of natural gases emitted from plants, called ethylene. This was important research for establishing the possibility of having plants for food aboard crewed spacecraft during interplanetary travel.

On Earth ethylene is harmless, but in an enclosed spacecraft it can build up and cause health issues for astronauts. Engineers created ethylene 'scrubbers' to take the gas out of the air and convert it into useful by-products. The process works by drawing the air surrounding the plants into tubes coated with titanium dioxide. When a UV light is passed over the titanium dioxide, the ethylene in the air is converted into water and carbon dioxide, which can be reused to maintain the plant's growth. Following its development, this technology has been widely adapted to remove particles, bacteria, viruses and mould from the air.

Mizuna lettuce growing aboard the ISS

SOLAR ENERGY REPOWERED

Although solar power cells were not invented by NASA, nor were they exclusively created for space exploration, research conducted in part by NASA propelled their development. This research began in the early 1980s and was intended to support the launch of the International Space Station (ISS). Without a charging cable to connect it to Earth, the ISS requires solar energy collected from the Sun. However, at the time solar cells were not ready for space travel, so NASA partnered with a company known today as PowerFilm. Together they created paper-thin solar cells that were flexible enough to be rolled up and light enough to be sent to the ISS. This solar film can convert 90 per cent of the light that crosses its surface into energy. The technology paved the way for more lightweight and efficient solar panel production on Earth.

Once known as 'slow spring back foam', temper foam returns to its original form after any applied pressure is removed

© Alamy

FOAM THAT REMEMBERS

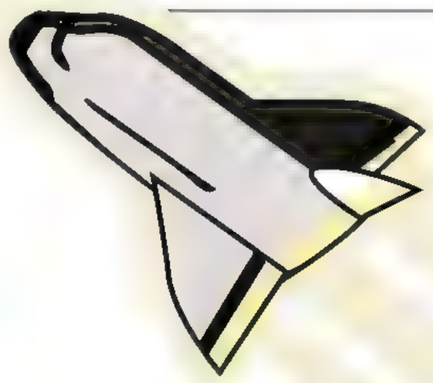
Initially designed to improve the seat cushioning and crash protection of airline pilots and passengers, memory foam, also known as temper foam, was a NASA creation from the 1960s. An engineer called Charles Yost had worked on the development of a recovery system for the Apollo Command Module back in 1962 and was later drafted by NASA to work on airline seating for crash protection. The result was a polymer-plastic material that could absorb a lot of energy from an impact but remain soft. The cushion-like material proved successful in air travel and exploded into other industries. Temper foam mattresses and other memory foam products hit the commercial market back in the early 1990s, and since then have diversified for use in hospitals, as shoe soles and even as a lining in American football players' helmets.

Space blankets, also known as emergency blankets, are often used after long-distance running to reduce the body's heat loss

SPACE BLANKETS

These foil blankets are often seen on the backs of marathon runners or incorporated into outdoor and camping products, but their initial use was to save a long-lost space station. During its launch in 1973, Skylab, America's first space station, lost one of its solar shields and began to overheat, reaching temperatures of around 54 degrees Celsius. To tackle this, NASA used thin metallic sheets to deflect heat.

Scientists created a metallic parasol that was taken into space aboard a crewed mission and attached to Skylab, ultimately preventing it from overheating and destroying the equipment on board. The lightweight material has not only been used on other spacecraft and satellites since Skylab, but has been used to create warming space blankets. Even though they were initially created to reduce heat, they are also good for keeping our bodies warm. These blankets trap up to 90 per cent of the body's naturally produced heat, which would normally be lost to the environment, thus keeping our bodies warm.



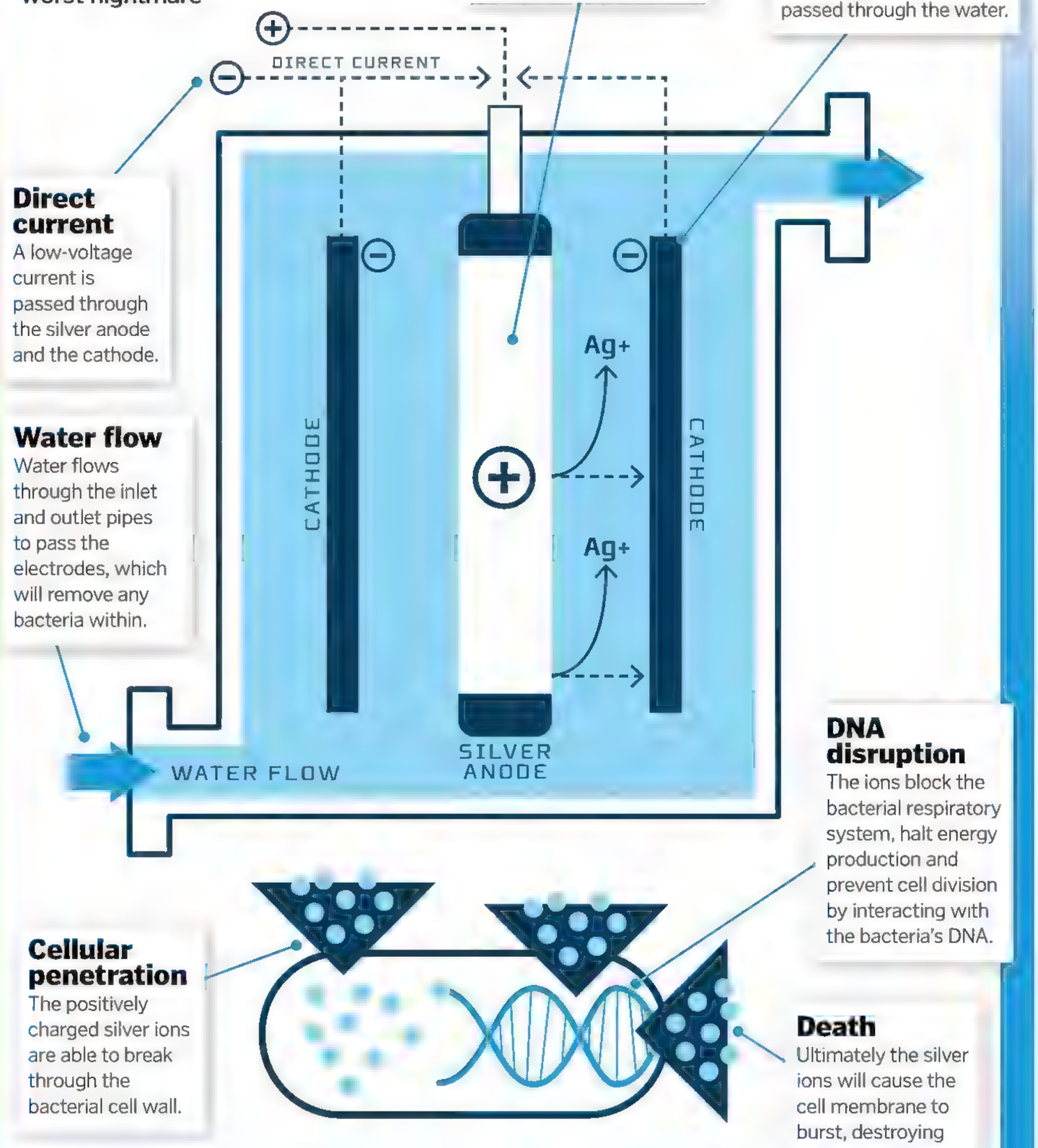
STAYING HYDRATED

Humans have been filtering and cleaning water for thousands of years. However, in the 1960s NASA researchers at Johnson Space Center took purification to the next level. What they created was a pocket-sized purification system that used silver ions to kill bacteria in water.

Silver ions naturally break down the bonds between the DNA and proteins in bacteria, ultimately destroying it. This process is exploited by the water purifier, which electronically releases copper and silver ions in the water to kill the bacteria and other single-celled organisms such as algae, which are then filtered out. The technology has been used to clean not only the water supply in space, but is also a common method on Earth to sterilise drinking water and kill harmful bacteria in pools and fountains.

Bacteria's silver bullet

Why metal ions are bacteria's worst nightmare



BABY FOOD

In exploring how to keep astronauts healthy in space, NASA scientists discovered an ingredient to keep us all healthy from birth. One of the vital omega-3 fatty acids humans need to develop a healthy brain, eyes and heart is called docosahexaenoic acid (DHA), and is predominantly found in a mother's breast milk. However, during the 1980s, scientists at NASA and a company called Martek Biosciences Corporation discovered that a type of algae produced DHA in high quantities. The research that came to this revelation was initially commissioned to explore the potential of algae as a food source for interplanetary travel, but researchers quickly saw the potential for use in baby formula. Currently more than 90 per cent of all infant formula on the market contains added DHA.

Vital nutrients found in baby food were first discovered during NASA's research into microalgae

© Getty

Freeze-dried food can have a shelf life of up to 25 years

© Getty

FREEZE DRYING

Taking food into space comes with a whole host of challenges. How do you store food in space? How do you make food last as long as possible? These are questions that scientists have been asking since before astronauts ventured into the unknown. Freeze-drying was found to be one of the best options. The process of this extreme dehydration wasn't invented by NASA scientists, however. It was the creation of French physician Jacques-Arsène d'Arsonval during World War II. However, it was NASA-funded research in the 1970s which developed it into the widespread preservation method used today.

Freeze-drying allows food to be preserved for longer while maintaining its nutritional value by exposing foods to a series of freezing and drying. First food is frozen solid in a freezing chamber, and then a vacuum pump is used to lower the air pressure within. Along with a little bit of added heat, this combination of the freezing temperature, low air pressure and then heat causes the frozen water content of the food to escape directly as vapour, bypassing its liquid state, known as sublimation. The process takes several hours, and once completely dried out the food is packaged in moisture-free containers to prevent rehydration.

5 FACTS ABOUT MEDICAL SPACE INNOVATIONS

1 Light-emitting diodes (LEDs)
These energy-saving bulbs are used to grow plants on the International Space Station, but also contributed to the creation of medical devices such as the WARP 10, which uses LEDs for muscle treatments.

2 Left ventricular assist device (LVAD)
NASA aerospace engineers helped to design a heart pump called an LVAD. This device helps to keep the heart pumping while a patient awaits a heart transplant.

3 Digital mammography
NASA commissioned the creation of high-tech silicon chips for digital imaging aboard the Hubble Space Telescope Imaging Spectrograph. These went on to be used in mammogram tests to detect breast cancer.

4 Ear thermometers
These thermometers use NASA and Diatek-developed infrared astronomy technology to measure the heat energy emitted from your ear.

5 Artificial limbs
Research into shock absorption materials and robotics for spacewalks have been adopted for dynamic artificial limb creation.

Without NASA's flight impact research, we might not have comfortable running shoes

© Getty

FUNCTIONAL FASHION

It was one small step for man, one giant step for humankind's functional fashion. One of NASA's many technology spin-offs was the revolution of safety suits and footwear around the world. Back in the early 1970s, engineers at Johnson Space Center were asked by the nation's fire chiefs to use their knowledge of astronaut spacesuit life-support systems to give their fire suits an upgrade, which at the time weighed around 14 kilograms. It took NASA four years, but engineers managed to create firefighter outfits that were around one-third of their original weight. Taking these spacesuit adaptations a step further, NASA developed a process called 'blow rubber moulding', inadvertently creating a new wave of athletic shoes. Initially created to make space helmets, the process involves blowing air into heated plastic or rubber to form a hollow mould. In the case of shoe development, this allows hollow soles to be made and filled with shock-absorbing material. It was a concept that athletic shoe manufacturer Nike found attractive. In 1978 the company launched the first-ever Nike Air, which encapsulated dense gases into rubber membranes to create an 'air' bag.

LOOKING INSIDE BODIES

CT (computerised tomography) scanners, are commonly found in hospitals around the world. However, the technology's origins can be traced back to pioneering work at NASA. During the Apollo lunar landing program in the mid-1960s, computer-enhanced digital image processing was created to enhance pictures of the Moon.

This technology paved the way for British engineer Godfrey Hounsfield to create the first CT scanner in 1972. This large piece of medical equipment uses a rotating X-ray source to take cross-section images of the body. A computer can then compile those images together to create a two- or three-dimensional image.

The technology then made its way back to NASA engineers in the late 1980s to allow them to take a look inside rockets. The Advanced Computed Tomography Inspection System (ACTIS) is essentially a giant CT scanner that enables aerospace engineers to spot any defects in the structure of their spacecraft or engines.

A CT scanner can be used to diagnose a wide range of injuries and diseases

Inside the scanner

How a CT scanner takes images of our insides

X-ray
X-ray beams are generated from a vacuum X-ray tube. These beams interact differently with different tissue and create contrasting images.

Fan
Fans are used to pump out any warm air from the gantry to keep the machine cool.

Monitor
The accompanying computer assembles the images of slices of the body on an adjacent monitor.

Cooling
To prevent overheating produced from the source, there are several liquid-filled cooling units.

Rotating detector
To collect images from all angles of the patient's body, the detectors circulate around the bed.

Gantry
Known as the ring tunnel, or gantry, this is where the patient will be positioned for the duration of the scan.

"A rotating X-ray source takes cross-section images"

TRANSPORT

130
Hot-air balloons

132
Landing a plane

THE ROAD TO ELECTRIC VEHICLES

Discover how battery power is transforming driving as we look inside an all-electric car

Words by **Ailsa Harvey**

In today's world we always have somewhere to be, and many of us rely on cars to get us there. These vehicles have been around since the late 1800s, and they are on their own evolutionary journey. From the clunky early models that only needed to transport people from A to B to be deemed successful, to today's more environmentally friendly vehicles, car companies are always looking towards the next best thing. One of their main focuses is removing the old engines of these vehicles and providing sustainable but desirable electric cars.

Going electric doesn't necessarily have to mean making a dramatic energy swap. In fact, there are three main types of electric vehicle, with only one completely removing the engine component from the car.

This battery electric vehicle, commonly known as fully electric, is for people who have committed to a new era of driving. Their high-capacity battery packs provide enough energy to drive the car as well as run all internal electronics. Fully electric cars are the only type of e-car to produce zero greenhouse gas emissions, and they allow a DC fast charge.

Plug-in hybrid electric vehicles act as a transition between fossil fuel and electric power. With both a small electric motor and a conventional engine, they can travel short distances at low speeds on electricity before the engine kicks in. The battery in these cars is charged through a plug and socket, like the fully electric vehicles. Finally, the hybrid electric also uses both power sources. The difference between this and the plug-in is that the electric energy it uses is generated by the heat given off by the car's braking system.

Driving innovation

How these cars suit the modern world

1 Happy planet
Swapping to electric transport contributes to better air quality as there are less greenhouse gases. All-electric vehicles produce no exhaust emissions.

2 Cheap to run
Per kilometre, electric vehicles cost about a third of the price to charge than it would to buy petrol for them. Electric motors also require less maintenance.

3 Noise reduction
Without a roaring, fuel-driven engine, electric cars usually only produce tyre noises and the sound of wind resistance.

4 Safer drive
As their motors are smaller than petrol or diesel-engined cars, their centre of gravity is shown to be lower. This makes them less likely to roll over.

5 At-home charging
Cutting out the dash to the petrol station, electric cars can recharge while parked at home. This makes the process easier and more reliable.

Car company Honda's solution to an electric future is the Honda e. As Honda's first fully electric launch, it's aimed to suit a city commute, with a maximum travel range of 220 kilometres, or 137 miles, per charge. Tackling an area most impacted by traffic-heavy roads, new electric cars like this could be a progression towards healthier cities and quieter streets.

How to recharge

Prepare your e-car for the road ahead

Choice of charge
The Honda e can either be slow, fast or rapid charged using the different connectors to supply a range of wattages. These are available at many public charging points and provide an option for fast and more frequent charging or a slower process with long-lasting power.

Status indication
This is an LED strip programmed to change colour based on the power status. When charging begins the light will turn blue, while red indicates an error. The light can be seen when approaching the car, even when the charging port is closed.

Charging port
Being in the centre of the bonnet, rather than on one side, makes the port more accessible. The car can be charged from either side or standing in front of the vehicle. The lid is made of strengthened glass and opens using the key fob.

Rapid connector
This car is being charged with the rapid DC charger. Using this the vehicle can reach 80 per cent charge in 30 minutes.

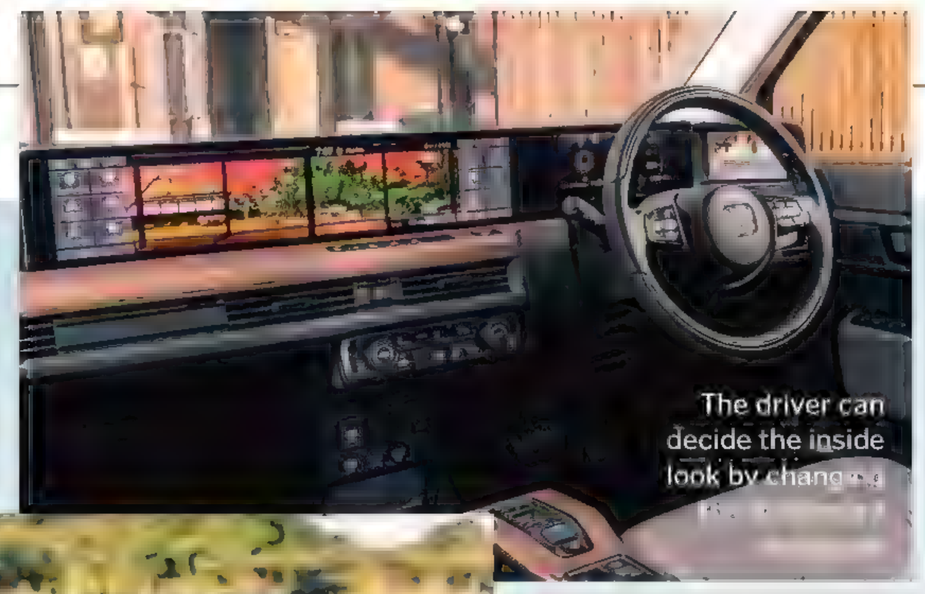
Type 2 connector
This type of connection can be used when charging the vehicle at home or at public charging points. When using 'fast-charging' mode, bringing the battery from 0 to 100 per cent will take roughly four hours, while on slow charge this will take about 12 hours. The cars are very rarely charged from a completely drained battery.

Combined charging system
This charging station can provide the driver with a choice of AC or DC charging. The AC connector allows slow and fast charging options, while the DC provides efficient rapid charging. The Honda e's charging inlet is shaped to fit both connectors.

All car images © Honda

INSIDE THE HONDA E

Meet the new, compact city car driving away from petrol and into the electric era



The panoramic aquarium is an extra feature which can be used while parked. It provides a calming lounge-style atmosphere, and you can virtually feed the fish by touching the screen

Digital dashboard

The dashboard is filled with electronic technology that's powered by the car's battery. It includes five screens to display apps and other features that aid driving. The car can also be connected to a smartphone to display music apps and contacts for in-car calls. Videos and films can only be viewed when stationary. A screen near the driver and one by the passenger can be switched so that tools for navigation and those for entertainment are nearest to the person benefitting from them.

Visualising power

Just as a petrol- or diesel-powered car displays how much fuel is left in the tank, behind the steering wheel a screen shows what percentage of charge is left in the battery. This gauge will tell you how many miles you have left and will alert you with visual warnings when it is getting low. When you receive this alert, there is still enough time to drive to the nearest charging point.

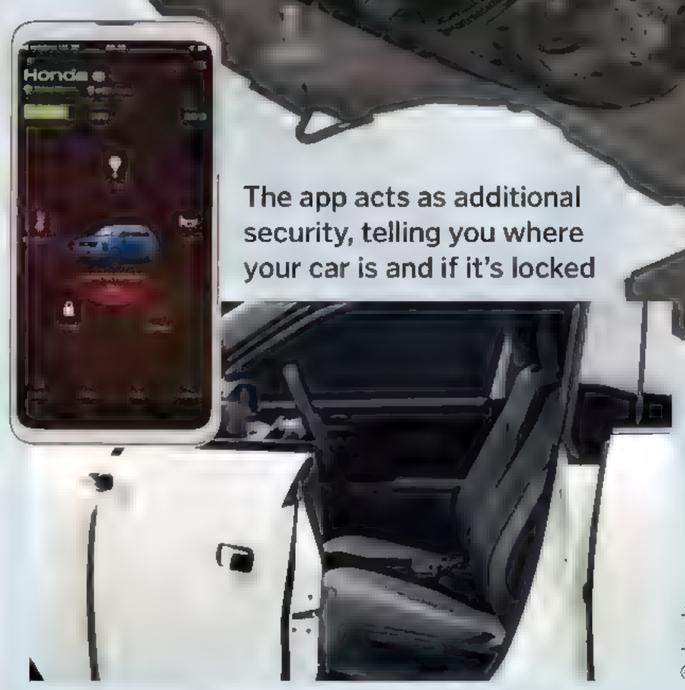
Cameras for mirrors

Wing mirrors are replaced with sleek and subtle cameras. The goings on from all around the vehicle can be monitored in front of you. These cameras stream live video footage onto screens at the edges of the dashboard and are positioned to minimise any blind spots. By having them inside the car rather than behind the windows, views are clear in all conditions. If cars approach too close from the sides, the camera footage will display distance lines to better inform you of how much space lies between the vehicles. When darkness falls, the Honda e's cameras adapt to night vision, maximising your visibility of the roads. They also feature glare resistance, preventing headlights behind you from limiting your vision.

The mirrors stick out for a wide view, but have a flat shape to remain aerodynamic

Car in your palm

The electric element isn't the only aspect of this car showing 21st-century changes. The MyHonda+ smartphone app serves as a remote car operator and tracker. By logging into the app you can lock and unlock the car, view the battery status and stop and start the charging process remotely while it is parked at your house. By providing a phone notification when the car reaches 15 per cent charge, drivers can be assured that they won't get caught short of power. Smartphone apps have proven successful for electric car owners to monitor their car, especially if they aren't used to having an electrically powered vehicle, as well as searching for public charging stations nearby.



The app acts as additional security, telling you where your car is and if it's locked

When the key fob is close, the car picks this up and the door handle pops out as the door unlocks

Leading the charge

As more new car models arrive, charging times and locations are becoming more crucial. In the future, many cars will have inductive charging pads built into the road, so you can charge your car while driving. With large parts already being developed, one plan involves transmitting charging pads into lanes to allow the journey to a charging station could be as simple as pulling over at the side of the road. This system is already being trialled in cities such as London and Seoul.

Parking assistance

Have you ever reversed into a space and needed your passenger to get out and guide you as you park? Taking over this role in the Honda e is the Parking Pilot. The sonar and camera technology can be used to better inform you of nearby objects and alerts you when you drive too close. On the display, an aerial view diagram of the car shows your position relative to surrounding objects. This helps the driver to view all the space around them at once, helping them park safely and with confidence.

Another option is to let the car park itself. By pressing the parking button, the car's four cameras and 12 sonar sensors scan the area for a suitable space. The cameras look for white parking lines on the road, while the sonar sensors check that there are no obstructions. The car completes this manoeuvre without the driver touching the steering wheel, gears, accelerator or brake.

Battery power

The 35.5 kWh lithium-ion battery keeps the car running on electricity up to 137 miles on a single charge. To optimise performance it has a thermal management system which adapts to heat or cool the battery in fluctuating conditions.

4.3 metres
The distance needed for the Honda e to perform a U-turn – this improves navigation on narrow streets

2030
Honda predicts that in ten years' time all cars will be focused on electrification, automation and connectivity

2022
Honda's goal for all its mainstream models in Europe to be electrified

50%
Wing mirror cameras increases the field of vision by half

8.3 seconds
The time taken for the Advance model to accelerate to 62mph

90mph
Its maximum speed is faster than a cheetah

The car has a maximum load capacity that's bigger than five bathtubs

861 litres

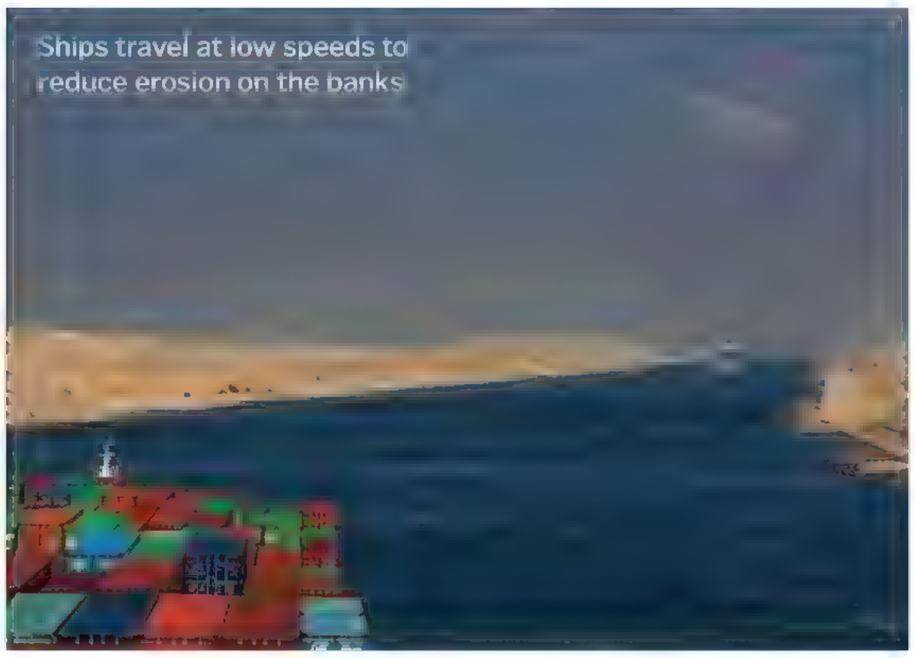
Strong core

For driving around the tight corners of cityscapes, the Honda e is designed with a 50:50 weight distribution and a low centre of gravity, placed 50 centimetres from the ground. The strong-but-lightweight chassis also comes with independent suspension. At its edges, protective panels protect the car's battery from any side collisions.

Rear-wheel drive

Installed to improve handling, the car's power is also sent to the back wheels. This helps to make driving feel more balanced and powerful. As more electric cars appear on the market, we could see the end of front-wheel drive. Their motors are relatively small compared to the engines of gas-powered cars, making them easier to mount at the front, back or both ends of the vehicle. In the Honda e, power at the rear improves the electric driving experience. Without having a heavy engine near the front, the back is where the weight of the car is pushed to during acceleration.

'Sport mode' uses rear-wheel drive, aiding increased responsiveness



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Why we need the Suez Canal

Humans changed Earth's geography to create this long waterway through Egypt, but what happens when the route is obstructed?

Words by **Ailsa Harvey**

For the seafarers of the world, land is an obstacle to navigate. But this doesn't always mean taking the long route around it to get from A to B. In the 1800s, a faster path was created for trade between continents. The result was the Suez Canal, a human-built waterway through Egypt.

This canal is now the shortest course that ships can take to travel between Europe and Asia, with 12 per cent of all global trade sailing through it. More than 50 vessels embark on the journey along this canal each day, which can take between 12 and 16 hours from end to end. The shortcut has allowed trading ships to shorten their delivery of a variety of products between some countries by a matter of weeks.

As the huge importance of this canal was realised, expansion projects have allowed the canal to accommodate larger ships and two-way traffic. But the southern stretch of the canal is much narrower, only allowing one-way traffic.

The Suez Canal was brought to global attention in March 2021, when one cargo vessel caused major problems for hundreds more. Called Ever Given, this ship was on its way to Rotterdam from China, encountering drastic difficulties during parts of its navigation. Amid a sandstorm, strong winds pushed against the containers on board the boat. This caused the pilots to lose control over the ship's positioning. The stern began to rotate, and the bow was forced too close to the side of the canal. The vessel became grounded, making contact with the shallows. The disruption lasted for six days and prevented $10 billion (£7.2 billion) a day being made through traded goods, highlighting just how essential this maritime trade route really is.

Canal channel

Discover how the Ever Given blocked the canal

Cairo
The canal borders the capital city of Egypt.

Stony bank
Beneath the water, loose stones line the banks. This meant that Ever Given was lodged deeper into the ground than it appeared from above.

Heavy load
Ever Given can carry 20,000 six-metre-long containers. The largest ships can carry up to 24,000.

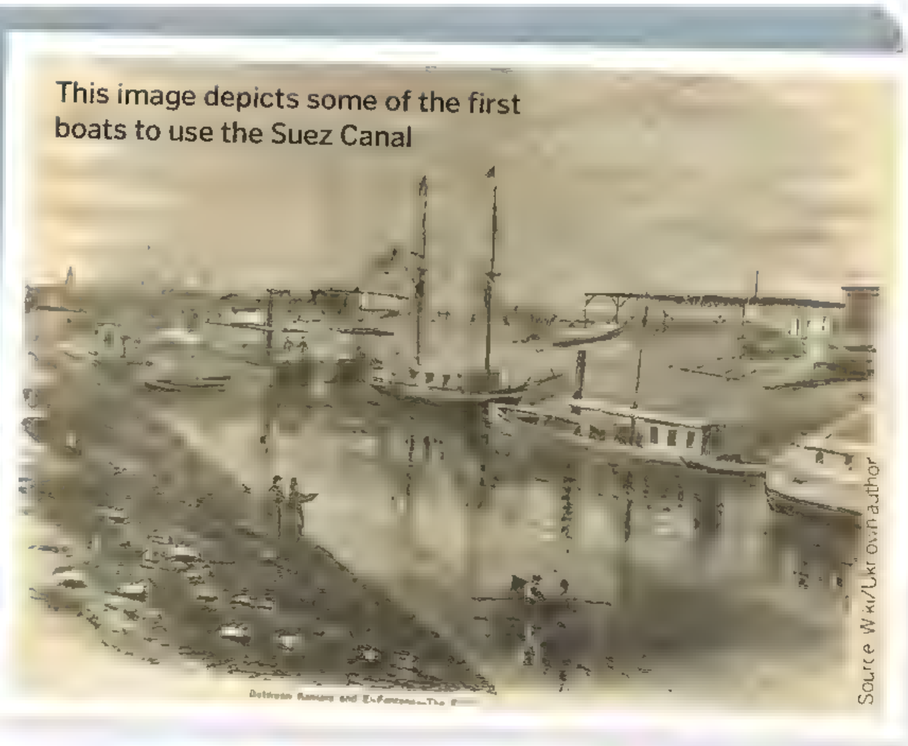
Waiting vessels
Other boats accumulated around the ship each day. Even with the wait, their journey would likely be shorter than taking an alternative route.

Ever Given
The ship that became stranded in the canal was 400 metres long and weighed about 220,000 tonnes.

© Alamy

Sailing through history

[redacted]


This image depicts some of the first boats to use the Suez Canal

Source Wiki/Ukr own author

© Getty

Lock free
The Suez Canal features no lock systems to control the water levels because the water levels at either end are roughly equal.

Shipping route
Stretching 120 miles in length, the Suez Canal is responsible for transporting 2.5 per cent of the world's oil.

Canal dimensions
The water where the ship ran aground is 24 metres deep. The boat was stranded horizontally across the 205-metre-wide canal.

Sinai Peninsula
The canal was dug out where the land between seas was narrower. After its completion, the Sinai Peninsula became separated from the rest of Egypt.

Freeing Ever Given

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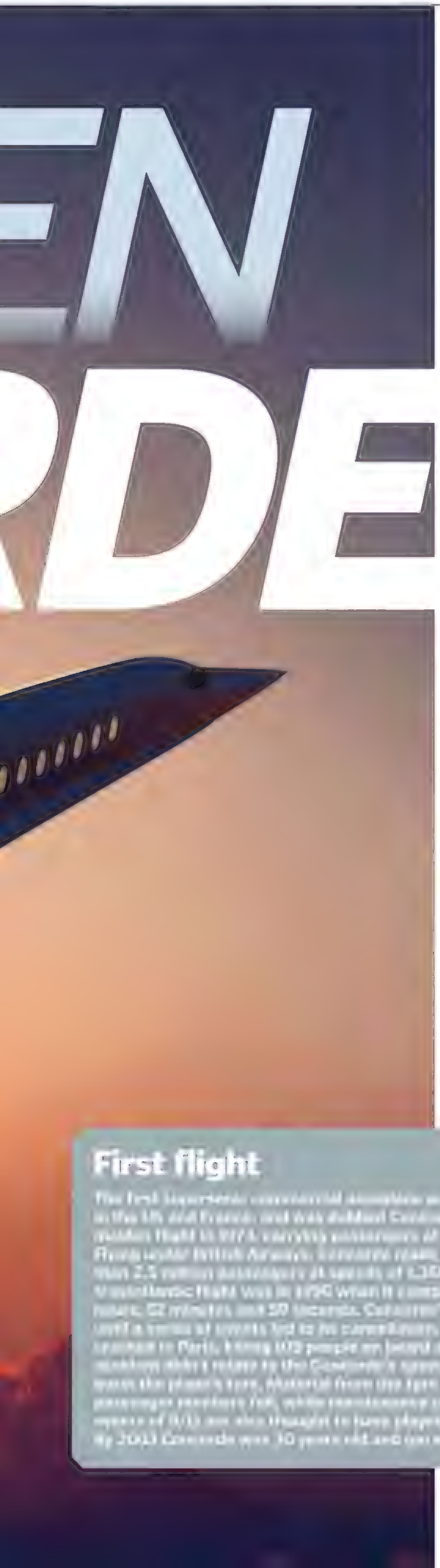
NEXT-GE CONCOR

IS THE FUTURE OF PASSENGER JETS SUPERSONIC ONCE AGAIN?

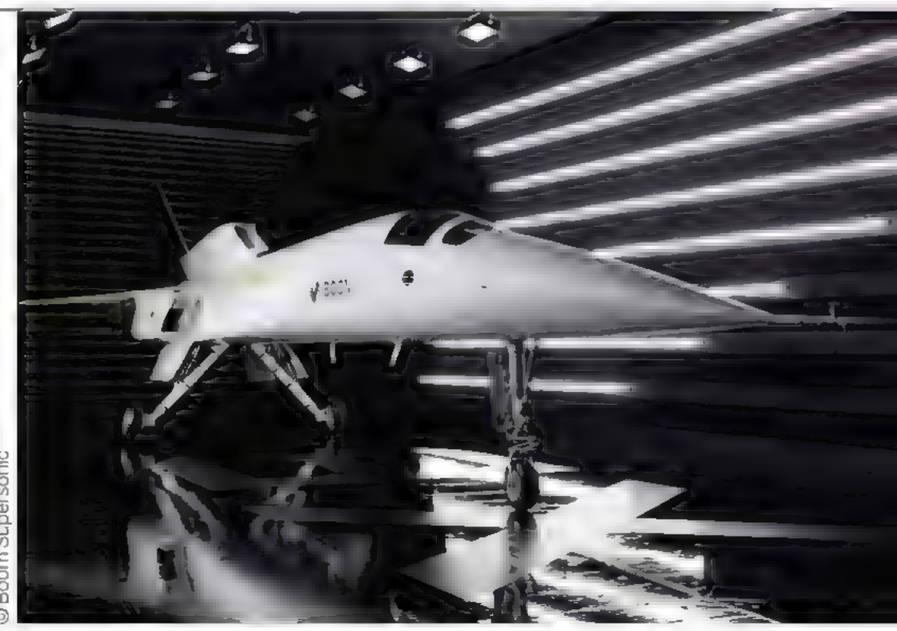
Scott Duffield



At the moment the future of international flight is unclear, with travel at its lowest during the ongoing global pandemic. However, planes will inevitably reclaim the skies once the world gets to grips with the coronavirus, and aerospace companies such as Boom Supersonic are ready and waiting with the next generation of supersonic aircraft.

Supersonic flight isn't a novel concept; it's commonly found in militaries around the world. However, commercial flights remain subsonic, except for Concorde's short time in the sky. Boom Supersonic is hoping to change that with its faster-than-sound successor, Overture, a commercial jet that can reach speeds over double the speed of sound at Mach 2.2. This would mean that a trip from Los Angeles to Sydney would take only eight-and-a-half hours as opposed to the typical 15-and-a-half hours.

The next-generation aircraft will be a 65 to 88 seater Concorde-style carrier which can cruise at altitudes of around 18,200 metres – current commercial planes typically cruise at heights of between 10,000 and 12,800 metres.



© Boom Supersonic

Boom Supersonic unveiled the highly anticipated demonstrator plane XB-1 in October 2020

To reach the desired supersonic speeds of 1,430 miles per hour, Overture has been designed to reduce the amount of drag – the force acting against a plane as it flies – it experiences. This will be achieved by its sleek aerodynamic body, made from lightweight carbon-fibre material. This material also prevents the expanding and shrinking some other materials experience at supersonic speeds. Large inlets will also be positioned around the aircraft to allow supersonic airflow to seamlessly pass over

Beating the boom

What happens when an aircraft travels faster than sound

Normal flight

The pressure waves produced by an aircraft travelling through the air slower than the speed of sound are evenly distributed around the aircraft. We perceive these waves as sound.

The speed of sound

When an aircraft reaches the speed of sound, pressure waves gather at the nose. The drag force applied to the plane increases and the airflow is compressed into a non-physical wall, referred to as the sound barrier.

Supersonic

When an aircraft reaches supersonic speeds, airflow cannot adjust the compression, causing a shock wave. This wave can be heard as a 'sonic boom' on the ground because the air moves to places of lower pressure.

© Getty

First flight

the plane and slow to subsonic speeds when entering the powerful turbojet engines, which provide massive amounts of thrust.

The passengers flying aboard a supersonic plane don't experience the external speeds, and flying at over 18,000 metres above the Earth's surface, there is almost no turbulence. Passengers may not even notice they have broken the sound barrier when Overture surpasses the speed of sound.

What's also impressive about the Overture's design is that Boom claims it will be made 100 per cent carbon neutral. The aerospace company has teamed up with Rolls-Royce to create a propulsion system that can fly using sustainable aviation fuels (SAF). In early 2019, the engines aboard Boom's proof-of-concept plane, the XB-1, successfully ran on approximately 80 per cent SAF from waste animal fats. Later that year, Boom partnered with Prometheus Fuels to incorporate technology that converts atmospheric carbon dioxide into jet fuel using clean energy. Along with making aircraft design recyclable and exploring noise-reducing technology in its engines, Boom appears to be keeping environmental issues at the forefront of its plane production.

Although Overture remains completed only on the screen of a computer, Boom has manufactured a demonstrator plane to showcase its efforts. Presumably named in honour of the plane that first broke the sound barrier in 1947, the Bell X-1, Boom's XB-1 supersonic is set to secure Overture's future in the skies. The proof-of-concept plane was rolled out in October 2020 and is scheduled to make its first test flight in Mojave, California, this year. The XB-1 is a scaled-down version of the final passenger plane – a third of its eventual size – but will showcase the feasibility of future commercial supersonic flight.

Production of Overture is estimated to begin next year, and it's slated to take flight in 2025, with commercial flights planned by 2029. That is all dependent, of course, on the success of XB-1's California flight tests and the state of a world recovering from global travel restrictions.

There are more than 500 transoceanic routes ready for Overture

© Boom Supersonic

AR ZONE!

THE XB-1

Meet the plane that's making commercial supersonic flight possible

21 metres
Around a third of the

425°C
The temperature that the XB-1's aft fuselage can withstand

~1.88 metres

Landing gear
The wheels of the aircraft are made from aluminium, titanium and AerMet 100, a type of superstrong steel.

AR ZONE! SCAN HERE

Overture would have enough speed and space to accommodate US Air Force missions

Faster Air Force

Although Overture could revolutionise commercial flight, it could also transform the transport of military personnel. In March of 2020, Boom was awarded a contract by the United States Air Force (USAF) to explore Overture's operations in the armed services. For one, it will take the form of Supersonic Aviation Assault Vessel, the world's first fleet of Quiet, Clean, Supersonic Platforms. "By cutting travel times, we make it possible for the world's most sophisticated warfighters to connect more frequently in person, meeting challenges and defeating potential crises as the greatest team," Boom CEO Blake Scholl said in a statement. "We're so proud to take another step forward with the Air Force to provide a capability for critical government activities." Scholl added that the launch was [illegible] Could this mean that Air Force One might one day go supersonic?

DID YOU KNOW? *Overture's price tag will be at least $200 million (£147 million)*

Inlets
Large inlets slow down incoming air from supersonic speeds to below the speed of sound before it enters the engine.

Engines
The aircraft is equipped with three General Electric J85-15 engines that produce a maximum thrust of around 5,580 kilograms of force.

Wings
The aircraft's ogival delta wings provide stability and control. This wing design helps to create lift, while reducing drag.

Fuselage
Carbon-fibre composites are moulded to create the plane's slender main body, which holds the pilots, passengers and cargo, called the fuselage.

Brakes
Anti-skid brakes allow the plane to land at speeds of up to 213 miles per hour.

~4,080 kilograms of force

3,488

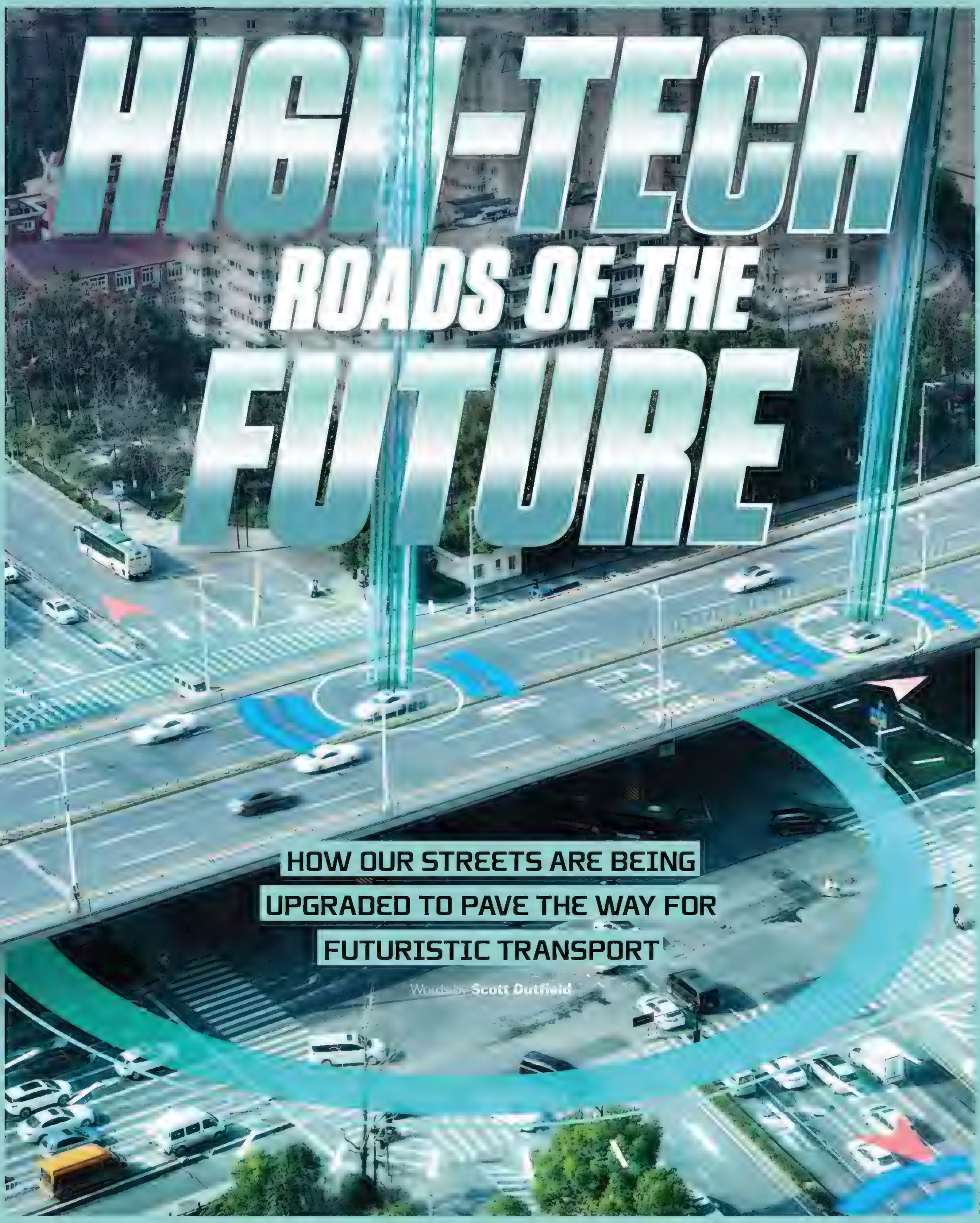
15,129

The proposed interior of Overture offe
single-seated comfort

© Boom Supersonic

© Illustration by Adrian Mann

HIGH-TECH ROADS OF THE FUTURE



HOW OUR STREETS ARE BEING UPGRADED TO PAVE THE WAY FOR FUTURISTIC TRANSPORT

Words by **Scott Dutfield**

© Getty

What is a smart road? As our cars become more and more technologically advanced, it seems that the logical progression would be for our roads to follow suit. In the UK stretches of 'smart motorways' have already been installed up and down the country in order to help manage congestion on especially busy highways such as the M1. These roads work using one of two types of sensor. The first is a series of copper loops installed below the surface in regular intervals of a few hundred metres. Connected to a computer for processing, these loops create an electric current whenever metal – such as a car or lorry – passes over them. Collating this information, computer software can calculate the volume of traffic and its speed.

Alternatively, some smart roads are equipped with side-fire sensors, which are placed on posts on either side of the road and cast a beam bilaterally. As cars pass through the beam, information such as speed, quantity and the size of the gap between vehicles can be monitored. Using either method of data collection, a computer can autonomously alter speed limits to ease congestion and open or close lanes along the motorway through overhanging signs.

However, since these smart roads began spreading along the UK's motorways back in 2014 there has been a rise in accidents occurring on the hard shoulder. Sensing an increased level of traffic, these signs might automatically signal a vehicle to drive on the hard shoulder to free up congestion. However, if a car has broken down on the hard shoulder and is awaiting assistance, they are vulnerable to a collision with an unsuspecting driver who has been using the lane as instructed. As a potential solution it's been reported that the UK government plans to stop the hard shoulder being opened as a driving lane.

There are currently around 400 miles of smart roads in use in the UK alone, with many more miles under construction. But is changing the speed limit and filtering lanes the best developers can do when it comes to upgrading our daily commute? It appears not. Across the world there has been a wash of developments in advancing the intelligence of our highways. From roads that glow to vehicle touchpad technology, our highways as well as transport as we know it, could soon be getting an upgrade.

Smart motorway network

There are hundreds of miles of smart motorways in England

© Highways England

A to B
As of October 2019 these are the smart roads currently in operation up and down England's motorways.

To ease congestion, smart roads can alter speed limits on both road signs and speed cameras

Future paths
There are many more smart roads currently under construction in the UK as part of the £15 billion investment by the government from 2015.

When good ideas go bad

They're an excellent addition to the roof of your home or beyond in a field to harness the energy of the Sun, but taking the power production of a solar panel and applying it to a road isn't without its shortcomings. Typically solar panels are manufactured using glass. However, a glass-topped road having the weight of passing cars wouldn't last long as a viable surface.

In recent years engineers have been developing ways to take solar energy, storing it and creating it with the prospects of applications. However, few have shown long-term viability. In France a valiant attempt at the technology was made in 2015 with the laying of 2,500 photovoltaic panels which make the kilometre of road in the northwestern town of Tourouvre-au-Perche. Rumoured to cost the 'Wattway' – made from a way a few millimetres thick, each panel is composed of photovoltaic cells submerged in a polymer resin to withstand the tonnes of traffic.

Promising the same grip for passing tyres as a conventionally laid road, these initial reports looked hopeful as an alternative energy source that could be implemented without interrupting existing infrastructure. However, that doesn't mean that it's the idea didn't live up to the hype. The Wattway couldn't handle the pressure of volume traffic and began to crack, not to mention the financial cost was substantial and the meagre maximum power output a single 1 m² Wattway is capable of, it will be a long time before solar powered roads power our motorways.

ROADS OF THE FUTURE

FOLLOW THE MANY AVENUES OF SMART ROAD ADVANCEMENT

Roads that recharge

As the threat of global warming forces us to search for alternative energy sources, why not look to the roads? With the right advancements, cars around the world could be producing energy as they go.

Piezoelectric roads mix traditional asphalt with piezoelectric crystals, using vibrations from passing cars to generate electricity. What makes these crystals unique is their atomic structure. Typically the atoms that build a crystal are symmetrically aligned and harmoniously bound. However, in piezoelectric crystals this atomic foundation isn't as symmetrical. As the crystals are forced under pressure and relaxed again their atoms are pushed closer together, producing an electrical charge. Under the weight of constantly flowing traffic, crystals embedded in the road have the potential to generate a new source of electrical power.

Piezoelectricity is no modern-day revelation, but one first demonstrated back in 1880. However, putting the power production into practice on a large scale, such as entire stretches of roads, has yet to be achieved. Lancaster University is one institution that seeks to change that. Last year the university was awarded £4.5 million to develop the technology and solve issues of energy efficiency and storage in roadside batteries.

Quartz crystals are piezoelectric, generating a small electrical charge when exposed to pressure changes

Sensing the weight of a vehicle, these smart road slabs can track the speed of each wheel

Built-in brain

What if the future of smart roads meant that they could know how many people are on the roads and send them updates on weather conditions, collisions or even charge cars as they drive? It's an ambitious feat in engineering, but one American company, Integrated Roadways, is developing a road to do those things.

Using built-in fibre-optic technology and integrated software, these factory-made and site-assembled modular pavements can detect and collect traffic data by recording the pressure applied to the roads. "We're basically making the road into a giant touchpad, but instead of looking for fingers, we're looking for tyres," says CEO and chief technology officer Tim Sylvester.

Thanks to built-in internet connectivity, these smart roads could keep you updated on driving conditions in real-time, but could also be used as a marketing tool to alert drivers of approaching businesses and amenities.

The team at Integrated Roadways has installed 0.5 miles of smart road in Lenexa, Kansas, as part of a development project. Having proved the technology works, Sylvester sees unlimited potential for this technology, with wireless charging for smart cars the next step.

"WE'RE BASICALLY MAKING THE ROAD INTO A GIANT TOUCHPAD"

A ground glow-up

[redacted]

Asphalt antifreeze

[redacted]

Inside a smart road

Discover the technology that makes these roads so clever

Fibre-optics
Distributed throughout the pavement, fibre-optic sensing cables measure the way the pavement deforms as cars pass over it. This deformation registers the presence of a car.

Sharing information
Within each slab are four routers that share information with their neighbours that continue along the road.

Modular
Almost like LEGO, each slab of pavement is assembled piece by piece to create a stretch of road. If one piece is damaged or utilities such as pipes underneath need maintenance, a panel can be easily removed and replaced.

Identification
The slab distinguishes between vehicles by identifying the four wheels on a car that are a fixed distance apart, travelling at exactly the same speed.

Connectivity
A local Ethernet network is built into the pavement system for connections to communication modules such as WiFi access, or multi-sensor units for temperature and weather detection.

MONSTER TRUCKS

WHAT POWERS MASSIVE TRUCKS THAT CAN DRIVE OVER ALMOST ANYTHING?

The phenomenon of monster trucking is a relatively new one. American 4x4 enthusiast Bob Chandler is credited with creating the first monster truck in 1974 when he raised the suspension on his Ford F-250 pickup truck and fitted it with immense 122-centimetre tyres. He then attempted to traverse over two scrap cars in the vehicle, and was surprised at just how easily the truck accomplished the task. A legend was duly born.

Bigfoot 1, as it became known, was in fact a stock pickup truck, with a beefier frame and engine later added to complement the changes in ride height and wheel size. Weighing in at a monumental 5,000 kilograms, Bigfoot 1 wowed the crowds with its original stunts of driving straight over and squashing conventional cars.

Despite these early revelations of newfound motoring entertainment, vast improvements in the build were needed to prolong the life of a monster truck. This soon led to a new, more durable design being implemented.

By the mid-1980s monster trucks used stronger axle housings with 'planetary gears' in the hubs to help turn the wheels and reduce stresses and axle-shaft breakage. Planetary gears work by a main gear in the middle – called a sun – engaging with three surrounding gears – called planets – at the same time. Once engaged the planets rotate around the sun, running along the inside of a ring and giving a three-to-one gear reduction ratio.

These vehicles, now called 'stage-two' trucks, also received heavier frames and axles taken from larger vehicles – but the chassis couldn't handle the extra weight. What's more, a stage-two truck now weighed around 6,800 kilograms. They also operated the antiquated leaf springs as found on early cars, or spring packs that still offered a notoriously harsh ride with little travel in suspension. Inevitably during the early stages of racing competition, drivers often got hurt.

The third and latest evolution of monster truck design has been the most significant. This upgraded iteration cuts costs while improving performance, repair times and driver safety. Introduced in the early 1990s, the main development was in suspension. As a result, current monster trucks now use a series of nitrogen-charged shock absorbers, which compress under load and then expand substantially. Current shocks have around a metre of travel, cushioning the driver on impact

"The chassis and frame are mounted high above the wheels, making it easier to traverse over large objects"

with the ground from a big jump. Indeed, shocks can now handle the impact of landing a jump from up to 60 metres.

Modern monster trucks also use flotation tyres, usually intended for agricultural use. The tyres need to flex as part of the suspension, making low-pressure agricultural tyres ideal. Due to the volume of air that goes into a flotation tyre, monster trucks only need about ten pounds per square inch (psi) of pressure per tyre.

As these trucks are seen as the brainchild of mid-western American petrolheads, it's only fitting that monster trucks are powered by another of America's greatest traditions: the V8 engine. Big Ford, Chrysler or General Motors engines are most commonly found in competitive monster trucks. Excessively tuned using superchargers and running on methanol, these engines can put down horsepower figures that hit quadruple digits. They can also catapult the five-tonne vehicles to 60 miles per hour in under five seconds. Such rapid acceleration also helps the trucks make large jumps from relatively small ramps, throwing the front of the truck into the air when needed.

Despite such immense power, you're unlikely to find a manual gearbox anywhere near a meaty stage-three monster truck, with the vehicle instead running automatic transmission. Because the driver must contend with steering the truck while operating the accelerator and brake pedals, the presence of a third pedal in the clutch would prove an unwanted distraction. Many monster trucks today use two-speed transmissions, and besides, some automatic transmissions can allow drivers to shift up or

Monster trucks by the numbers

2,000bhp
Horsepower produced by a monster truck engine

10psi
The average tyre pressure for a monster truck

72.42m
The longest ramp jump by a monster truck, recorded in 2013 by Bad Habit

91cm
The amount of 'wheel travel' nitrogen shock absorbers allow stage-three monster trucks

$250,000
The annual cost of running and maintaining a monster truck

168cm
The average tyre height of one of these trucks

5
The average Monster Jam truck team burns their way through several gearboxes a year

9,423cm³
The average size of the displacement of a monster truck's engine

25
scrap cars are crushed by Monster Jam trucks in a typical show

Getty Images Corbis

down without the need for a pedal – less for the driver to have to pay attention to.

On the inside, a stage-three monster truck now employs a complex tubular design made from steel and chromium-molybdenum for its frame and chassis, which strengthens the vehicle and protects the driver. This is where the conventional pickup truck ends its association with monster trucks. Instead of using an 'original equipment manufacturer' body, each frame and chassis is custom built. The chassis and frame are mounted high above the wheels, giving massive ground clearance and making it easier to traverse over large objects such as cars and allowing for long travel from the suspension when landing a jump.

A lightweight and durable fibreglass shell covers the frame and engine. Any lights, grilles and doors are merely decorative, saving further weight and ensuring the bodywork is easier to respray after repairs. Moving ever further from their ancestral pickups, some monster trucks are modelled on non-vehicular objects, such as Monster Mutt, or Batman, styled according to the famous superhero. With no conventional doors to climb in and out of the truck, the driver instead enters and exits via an escape hatch in the middle of the cockpit floor.

Monster trucks have traditionally followed a layout akin to that of a conventional American road vehicle, with a front-mounted engine and a driving position to the left of the cabin. However, some of the more modern monster trucks now operate with the driver sitting in the middle of the cabin, with a mid-mounted engine roaring loudly underneath. With more weight now in the centre, monster trucks enjoy greater balance, making them more nimble when performing stunts.

Front- and rear-wheel steering on today's trucks allows them to corner faster and gives the driver a few more valuable seconds to make a turn after coming down from a big jump.

A monster truck built for competition can take three months to a year to build. This depends on the intricacy of the tubular frame and the overall truck's design. Once fully built a monster truck can dominate and even decimate a terrain littered with human-made objects thanks to its excessive weight and power. They may be loud, lairy and disproportionately scaled, but make no mistake: a monster truck is absolutely an engineering marvel.

> "Any lights, grilles and doors are merely decorative, saving further weight"

As such, motorsport involving monster trucks is very popular. Many of America's top-end monster trucks take part in the world-famous Monster Jam, a globetrotting series in which experienced drivers perform sprint races and freestyle events to tens of thousands of spectators. A sprint race is a dash to the finish line between two trucks at a time, where the winner goes through to the next round until just one truck remains. The freestyle event, meanwhile, gives trucks around 90 seconds on the arena floor to dazzle three judges. Stunts typically include jumping up onto and then crushing cars, as well as performing sky wheelies and multiple doughnuts.

Capable of 0 to 60mph in under five seconds, these trucks are mean machines

Taming monsters

Bigfoot: the original monster

Bigfoot is the first and most famous monster truck. Chandler's original was retired in the mid-1980s, but he has continued to name each of his many trucks since in numerical order – the latest is Bigfoot 21

V8 engine
Textbook American muscle engines are favoured for their large capacity and ability to handle extreme power and stress.

Transmission
Two-speed transmissions are mounted high for maximum ground clearance.

Frame
The frame is tubular-welded for rigidity, helping the truck to handle and control better. This also protects the driver in case the vehicle is rolled.

Fibreglass shell
Monster trucks use a fibreglass shell as it's extremely lightweight and simple to repair.

Flotation tyres
Taken from agricultural machines, these make climbing objects easy and allow a cushioned landing afterwards.

Long-travel shocks
These nitrogen-charged shock absorbers have up to one metre of travel to ensure a cushioned landing from big jumps.

Link bars
The four main bars that link the front and rear axles to the frame. They can be adjusted to control how much traction the truck can get.

"A monster truck is absolutely an engineering marvel"

Size matters

	Monster truck	Family saloon	London bus	Smart car	Motorbike
Length	6.0m	4.6m	10.2m	2.69m	2.18m
Width	4.5m	1.9m	2.5m	1.6m	0.73m
Height	3.6m	1.5m	4m	1.5m	1.2m
Weight	4,900kg	2,500kg	13,000kg	820kg	170kg

Hot-air ballo

How do these gasbags get off the ground and return to Earth safely?

A hot-air balloon consists of three basic parts: an envelope big enough to displace a large amount of air, burners beneath the envelope to heat the air inside and a basket in which to sit back and enjoy the ride. The scientific principle that enables this lift is convection, or heat transfer.

Heating the air inside the envelope causes it to expand, forcing some of the air out of the envelope. The weight of the air inside then decreases, making the balloon lighter and giving it lift. Once the burner is shut off, however, the air inside cools and contracts, causing cold air to rush in from below, weighing the envelope down and causing the balloon to descend. If the burner is powered up intermittently, the balloon can maintain a pretty much constant altitude. Hot-air balloons have an upper limit, because at very high altitudes the air is so thin that the lift is not actually strong enough to raise the balloon.

Because hot-air balloons have no real means of changing direction other than upwards and downwards, the vehicle will drift along with the wind. However, a skilled balloonist can move somewhat horizontally by altering their altitude. Wind is known to blow in different directions at different heights, so the pilot can ascend to descend until they find the appropriate wind to send them in the direction they wish to travel.

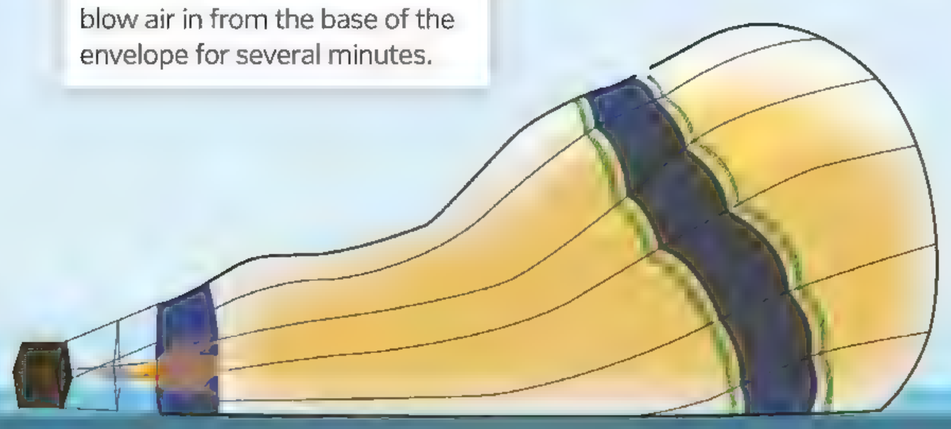

A colourful display

Envelope
Reinforced ripstop nylon fabric – also used for kites, sails and sleeping bags – is the principle material used for hot-air balloon envelopes. This lightweight fabric can also be coated with silicone to make it more hard-wearing.

What goes up...

2 Erection
To get the inflated envelope off the ground, the propane-fuelled burner beneath the envelope is placed at the entrance to the envelope and blasted.

1 Inflation
A balloon crew inflates the envelope using a powerful fan to blow air in from the base of the envelope for several minutes.



4 Air expands and rises
Warm air expands and rises, causing about a quarter of the air to exit through the bottom of the envelope.

3 Burner on
The burner heats the air inside to about 100 degrees Celsius. This causes the air particles to gain energy and move about faster and further apart.

5 Ascent
The balloon ascends because the air inside the envelope is lighter and less dense than the cold air outside.

cons

Parachute vent
If the balloon needs to descend quickly, colder air can enter via a parachute valve or vent in the top of the envelope, controlled by a cord pulled by the pilot.

Gores
To create the balloon shape from a flat piece of material, it must be cut into long panels from the crown to the base, called gores. These gores are then stitched together to create the shape.

Turning up the heat gets you airborne

7 Air contracts
The cooler air contracts, leaving space inside the envelope to suck in more cold air from below.

8 Descent
The increased weight of the cooler air inside the balloon exceeds the upthrust. The balloon will start to sink.

9 Landing
By gently controlling the burner and descent, the balloon will normally come in to land bouncing along the ground before stopping.

10 Landing site
Given the relatively uncontrollable nature of directing a hot-air balloon, the landing site cannot always be predicted, and so the pilot must select a large enough area free from pylons and bodies of water where they can lay out the envelope.

6 Burner off
Shutting off the burner causes the air to cool down.

Propane tanks
Compressed liquid propane is stored in lightweight tanks in the basket.

Skirt
The flame-resistant material at the base of the envelope is called the skirt. This stops the rest of the envelope from catching fire.

Burner
Liquid propane flows from the tanks through steel pipes coiled around the burner. When the balloonist triggers the burner, liquid propane flows out and is ignited by a pilot light. In the meantime this flame heats the metal pipes, turning the liquid propane into a gas that is more powerful and fuel-efficient than the liquid when it's cold.

Basket
Traditionally a hot-air balloon's basket is made of wicker because it's durable, flexible and lightweight. Today hot-air balloons can come with double-decker baskets that seat 50 people if necessary. Enclosed gondolas are also available for serious, long-distance ballooning.

LANDING A PLANE

Find out how pilots get tonnes of metal down safely to the tarmac

Landing a plane is the most delicate part of a flight. It involves turning a flying craft into a ground vehicle, bringing hundreds of tonnes of mass to the ground without incident while shedding speed along the way. Aircraft will naturally fly: so long as they have sufficient fuel, their aerodynamics are designed to keep them moving. To change this, pilots not only have to reduce engine power, they also must slowly adopt a 'dirty configuration', using aerodynamic drag to reduce speed.

The landing procedure begins miles away from the airport. During this time, many changes in altitude, speed, direction and overall aircraft set-up must be completed. This is mainly conducted in dedicated 'step down airspace', defined by air-traffic control. Passengers are told the landing procedure is due to commence, and are instructed to return to their seats and fasten their seat belts. This is a legal requirement.

At night the cabin lights are dimmed before the landing procedure commences, and window blinds are raised. This is so that in an incident, passengers will be less disorientated. Dimming the lights reduces glare and means eyes will already be adjusted to dim conditions. It will also let some light into the cabin and allow passengers to spot dangers.

Landing is a two-stage process: the approach to landing and landing itself – which will only be successful if the approach is good. During the approach phase, pilots slow the plane from cruising speed to an approach speed, from which they can descend gently to a landing speed. Pilots allow the plane to contact the ground with the lowest possible vertical and horizontal speed.

As throttling back is insufficient to fully slow an aircraft, the additional configuration changes are filtered in at defined approach points. These include gradually raising flaps, and later on in the procedure extending the landing gear. Indeed, such is the drag created in doing this, some engine power must actually be reapplied to compensate.

The pilot's main goal during descent is to reach the runway at a precise point, and they are able to quickly form a mental picture of the destination landing strip as all runways are given a number from 01 to 36. This is their heading, where 36 equals 360 degrees, or due


The air-control tower can help guide a plane down onto the runway

north. It enables pilots to quickly visualise the landing direction, and judge how wind conditions may affect this. Runways can have two numbers, for example 34 and 16. They are separated by 18 because it is the same runway operating in two directions.

The final approach procedure is initiated in a 30 to 50 mile radius. Air-traffic control (ATC) staff on the ground receive 'their' approach aircraft from fellow controllers on route. The controller's job is to find a space for the approach aircraft with a safe separation from others entering the centre airspace; they all blend together, with the required separation, into a separate channel for final approach to the runway.

Final approach requires stated clearance from ATC. Sometimes a landing must be aborted at the last moment, either because of an emergency alert from air-traffic control or an override by the pilot. This is called a 'go around' – the aircraft will pitch up sharply, full power will be applied, landing gear and flaps will be tucked away and a very steep climb will be felt.

This can be alarming for passengers, but is actually a specific procedure pilots are trained for. It usually occurs either because a plane is still occupying the runway, or the pilots do not have sufficient visual references to land safely. Passengers will be familiar with delays from being kept in a holding pattern. This is for their own safety and ensures the pilot has the time and space to complete their landing procedures, avoiding 'go around' emergency calls in the process. Holding patterns are predefined and dictated by ATCs in the control tower.

When it's busy, ATC will sometimes specify a defined airspeed for pilots to maintain, usually within an accuracy of ten knots. This is to keep the aircraft in sequence with those in front and behind – it is how the rate of approach to crowded airports is controlled.

ATC allows two forms of instructions to pilots, which will be stated before the procedure commences. The descent itself can be under specific altitude instructions which pilots must obey – this is to further help in traffic separation. Alternatively, the aircraft is cleared to descend at

"The pilot's main goal is to reach the runway at a precise point"

the pilot's discretion. This means the pilots themselves decide speed and rate of descent – the only proviso is that once they leave an altitude, they cannot return to it.

On the technical side, landing procedures are managed by an instrument landing system (ILS). This uses radio beacons situated on the ground to precisely guide a plane down with immense accuracy. An ILS follows a specific glide path that helps the plane follow an 'ideal' three-degree angle to the runway.

ILS radar is often supported by an approach lighting system (ALS) – lightbars, strobes and so on, which are situated at the start of the runway. They are a big aid to pilots, helping them switch from instrument flight to visual flight – and they can also extend the operating range of the airport because they count as part of a 'visual approach'. Pilots must be able to see three-quarters of a mile to the runway: with high-intensity ALS, this can be reduced to half a mile or more if lights extend to parts of the runway.

The final seconds before touchdown are when many passengers hold their breath. Just before


Monitoring each flight's progress is essential for avoiding any midair collisions

an aircraft touches the ground, the nose will be raised up. This is called a 'flare', and means the main landing wheels touch the ground first. The perfect landing will see the wheels touch the ground just as lift on the wings completely falls away and the plane 'stalls'. To feel hundreds of tonnes of mass controlled in such a precise way is extremely satisfying.

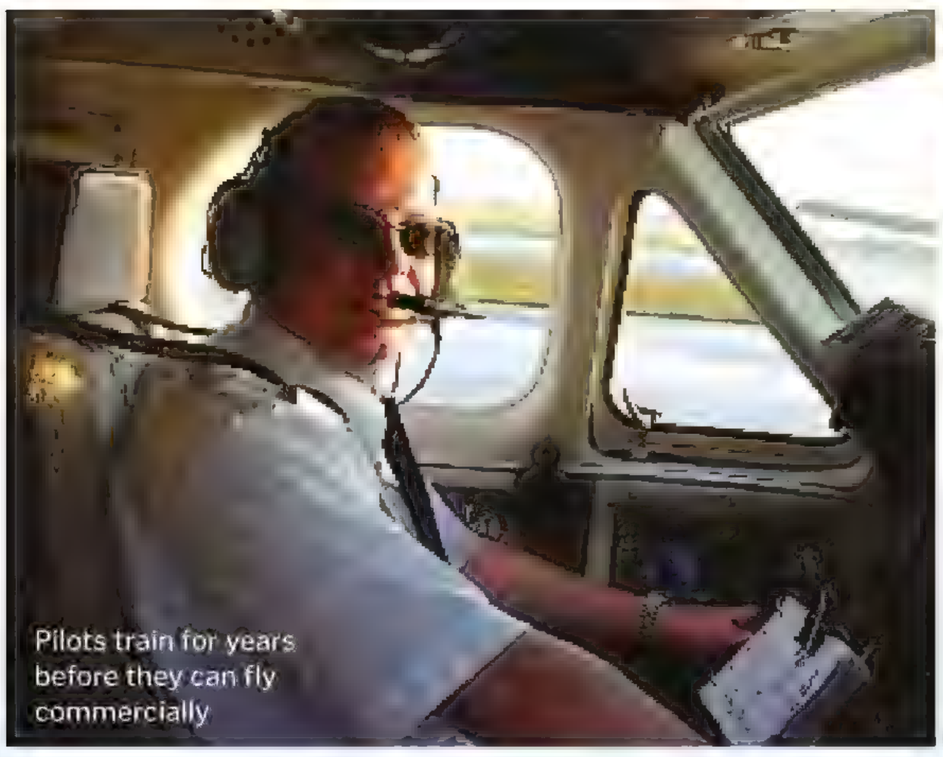
When the rear wheels are on the ground, the pilot does not lower the nose – it drops of its own accord. It does so because as the aircraft loses speed, the flight controls continue to lose effectiveness so gravity can take over. Once all wheels are on the ground, the aircraft is in rollout mode.

Here the flying machine is turned into a ground machine – and must be stopped before the end of the runway. On large jets, the first method of doing this is to raise more flaps to increase drag while engaging reverse thrust on the jet engines. As forces build, pressure on the landing gear increases.

Once there's enough mass pressing down on the wheels, the pilot can apply the brakes. Passengers feel this two-stage deceleration in landing – first the engines will roar, and then there will be a slight jolt as the brakes come on. The length of this rollout process depends on the weight of the plane, the runway's gradient, condition and elevation, ambient temperature, brake effectiveness and pilot technique.

Autopilot can actually perform the complete procedure right up to touchdown and rollout. What autopilot cannot do is control the ground taxi process; this will always be done by the pilot, using guidance from ground control. On the ground the aircraft will taxi to its final position, where passengers can disembark.

"The final seconds before touchdown are when many passengers hold their breath"


Pilots train for years before they can fly commercially

Instrument landing system explained

An ILS is installed at most important airports, helping land planes accurately, safely and efficiently

Approach and landing

1 Miles of landing
The landing process may already be underway by the time you buckle your seat belt.

2 Air-traffic control
The aircraft will be directed to an ILS localiser via defined headings.

5 Control tower
The aircraft will be supported by air-traffic control based at the tower.

1 Holding stack
Radio beacon
Terminal building
Control tower
Apron
Runway
Secondary radar
Glide path
Outer marker
Eight miles
Middle marker
0.6 miles
Primary radar

10 Terminal and exit
The aircraft will be directed to the parking apron. Passengers will disembark and head to the terminal.

3 Holding stack spacing
All aircraft landing at an airport will have already been widely spaced many miles before descent.

9 Rollout
The pilot will use aerodynamic devices to create drag and slow the plane, then apply the brakes.

4 Marker post guidance
Pilots know how far from the runway they are thanks to marker posts.

6 Pilot remains in control
Air-traffic control manages plane positioning, but pilots always make the final decision in an emergency.

7 Glide path
Aircraft descend at a glide path gradient of around three degrees – ILS is calibrated to ensure this.

8 The perfect touchdown
The wheels of an aircraft should ideally touch the ground just as lift on the wings reduces to a stall.

Outer marker beacon
The outer marker sounds an alert at up to 8 miles away from the runway, and flashes a purple or blue light on the instrument display.

Directional system
An ILS is directional, so is located on either end of a runway. Additional marker beacons are sometimes included, providing further information to approaching planes.

ILS establishment
Aircraft need to come within 2.5 degrees of the localiser course in order to become established on a final approach route.

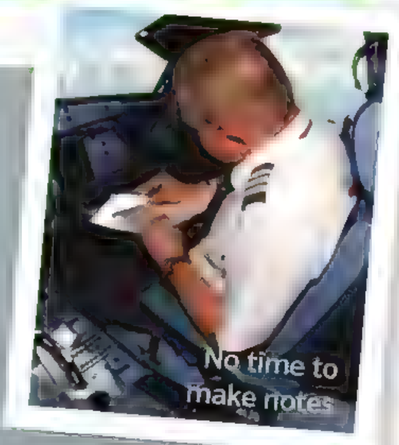
ATC lead
Air-traffic control directs aircraft to the localiser using defined headings – this keeps good and even spacing between planes.

Localiser modulation frequency

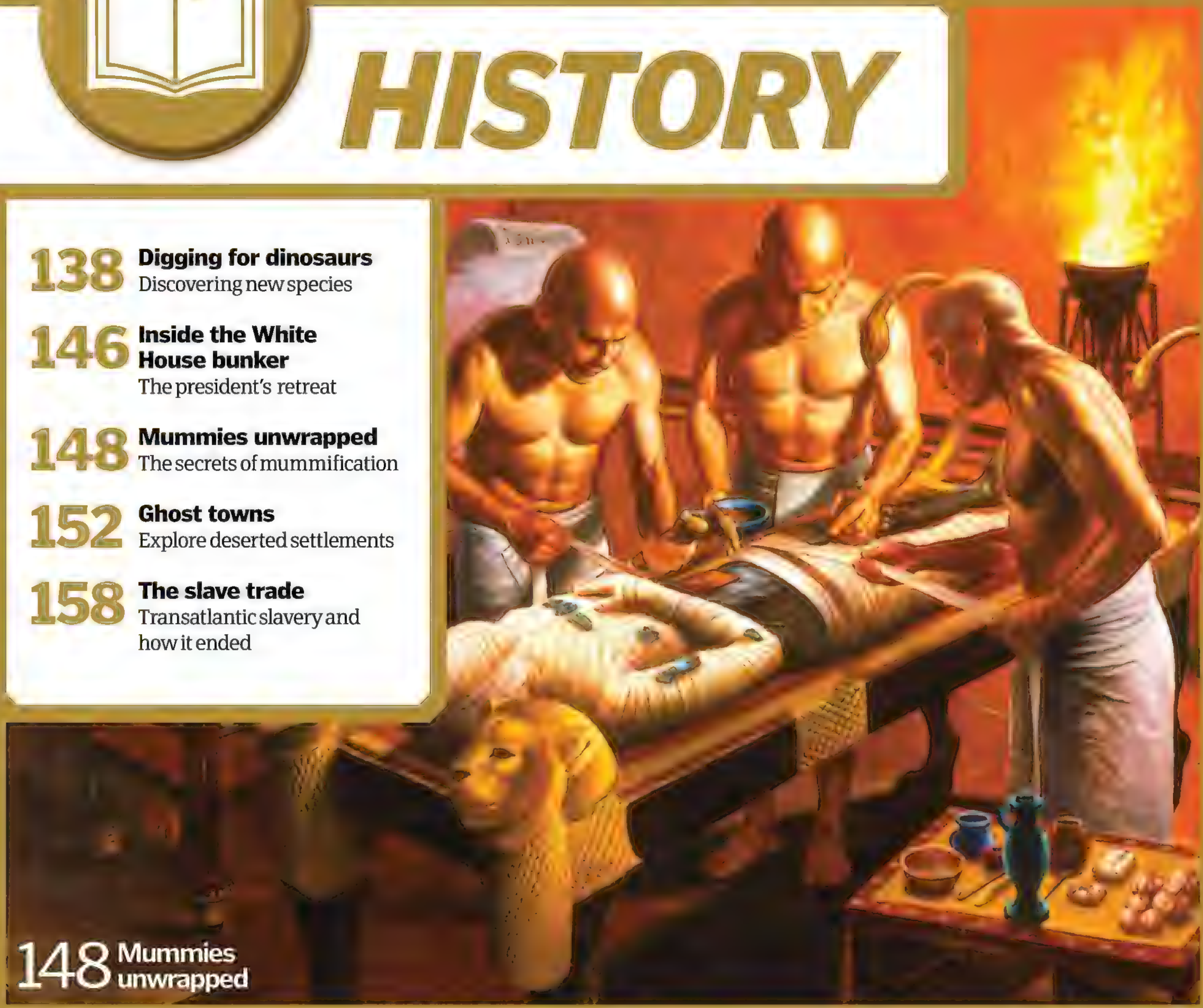
Glide slope modulation frequency

Landing a plane in an emergency

Let's hope you never have to use this...



HISTORY



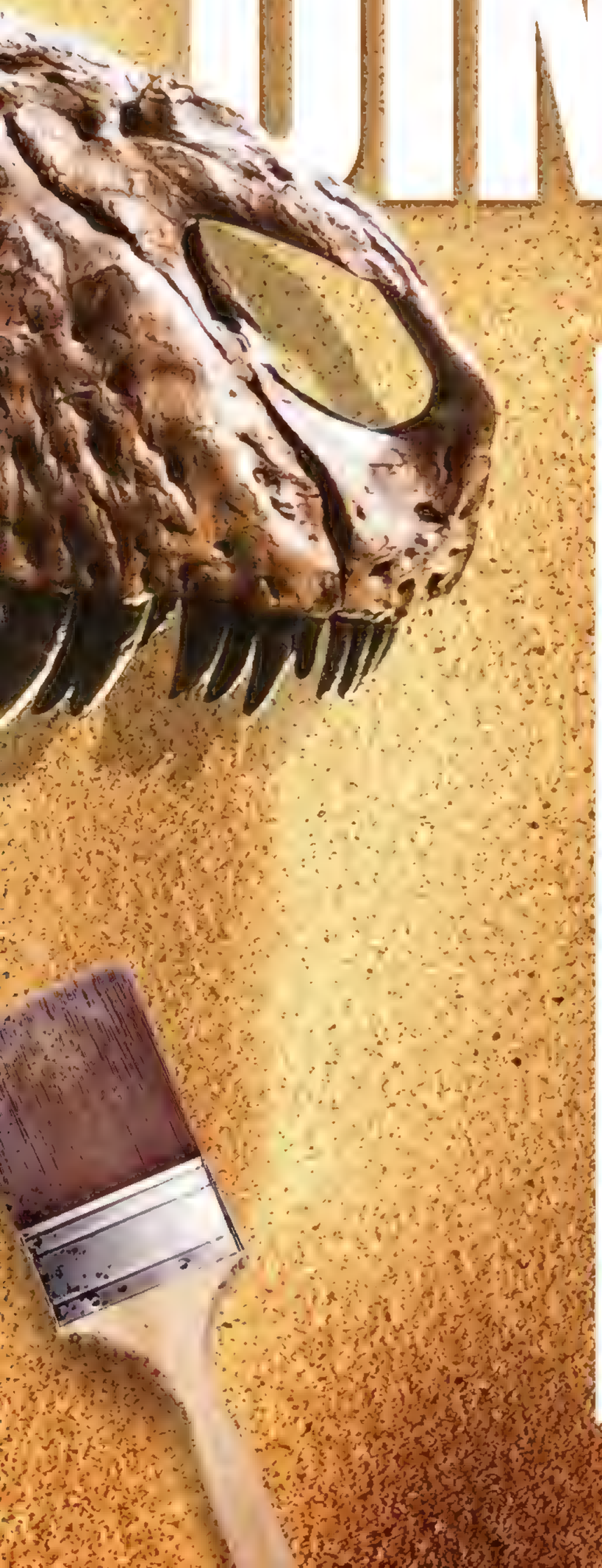
146
Inside the White House bunker

Though rarer, entire skeletons have been found perfectly preserved

Excavating is a slow process to avoid damaging the find

DIGGING FOR DINOSAURS

Discover how a fossil hunter recently discovered a new ancient species. Could you make the next big find?



Words by **Ailsa Harvey**

How do you look for something that you aren't yet aware existed, from a world you can only try to imagine? It might seem impossible for us to study a species that we have never coexisted with, but this is something palaeontologists and fossil hunters do every day.

When humans first encountered dinosaurs, they had been extinct for over 65 million years. Everything we have come to know about dinosaurs today has been learned through our understanding of the planet's geology and analysing the ancient remains of these creatures. For this to happen, dinosaurs needed to have a lasting impact on the world, enduring tens of millions of years held inside solid rock. Luckily the remains of many types of dinosaur were preserved in the ground until humans could uncover them – and their secrets.

Fossils are impressions of ancient life, contained in the Earth's crust as a memento of life before the present. To palaeontologists they are hidden treasures, each with valuable information to share about a past geological and environmental age. The secret to their lasting form comes from the way they died. To become a fossil a dinosaur needed to take its last breath near water, or to have been buried alive.

Most dinosaurs wouldn't have died this way, so their remains would have deteriorated and can never be discovered. However, even for those that perished in one of these two ways, their bodies had to be surrounded by certain essential minerals to convert them into rock. Fossils are formed deep underground, where oxygen levels are so scarce that no bacteria can survive there. This means the body is unable to decay and lose its shape.

It's odd to think that these bones could be frozen in time only to be neatly retrieved from the ground as an almost-undisturbed stone skeleton. In some cases, not only are scientists presented with a perfect anatomical specimen to study, but they get an insight into a day in the life of a dinosaur – albeit their last day. Those that were suddenly buried alive can be retrieved in the exact position they died in. These are extremely rare fossils, but can provide information about the way a species lived.

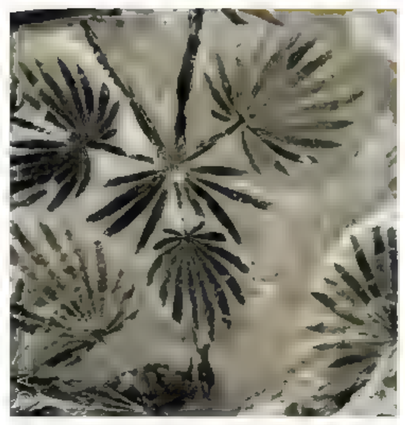
Around the world, new dinosaur species are constantly emerging from rock faces, sandy dunes and clay-rich soils. But why are they being found now? To retrieve a fossil from sediment, the dinosaur first needs to be within reach. Sometimes it simply means being in the right place at the right time. You need to be near the land where the fossil has been held for millions of years just after the forces of nature have removed its rocky casing. The fossil then needs

5 FOSSIL TYPES

Mold
The rock of a mold fossil details the outside of the organism. After the sediment around it hardens, the buried plant or animal is dissolved by water, leaving an empty mold for a fossil.

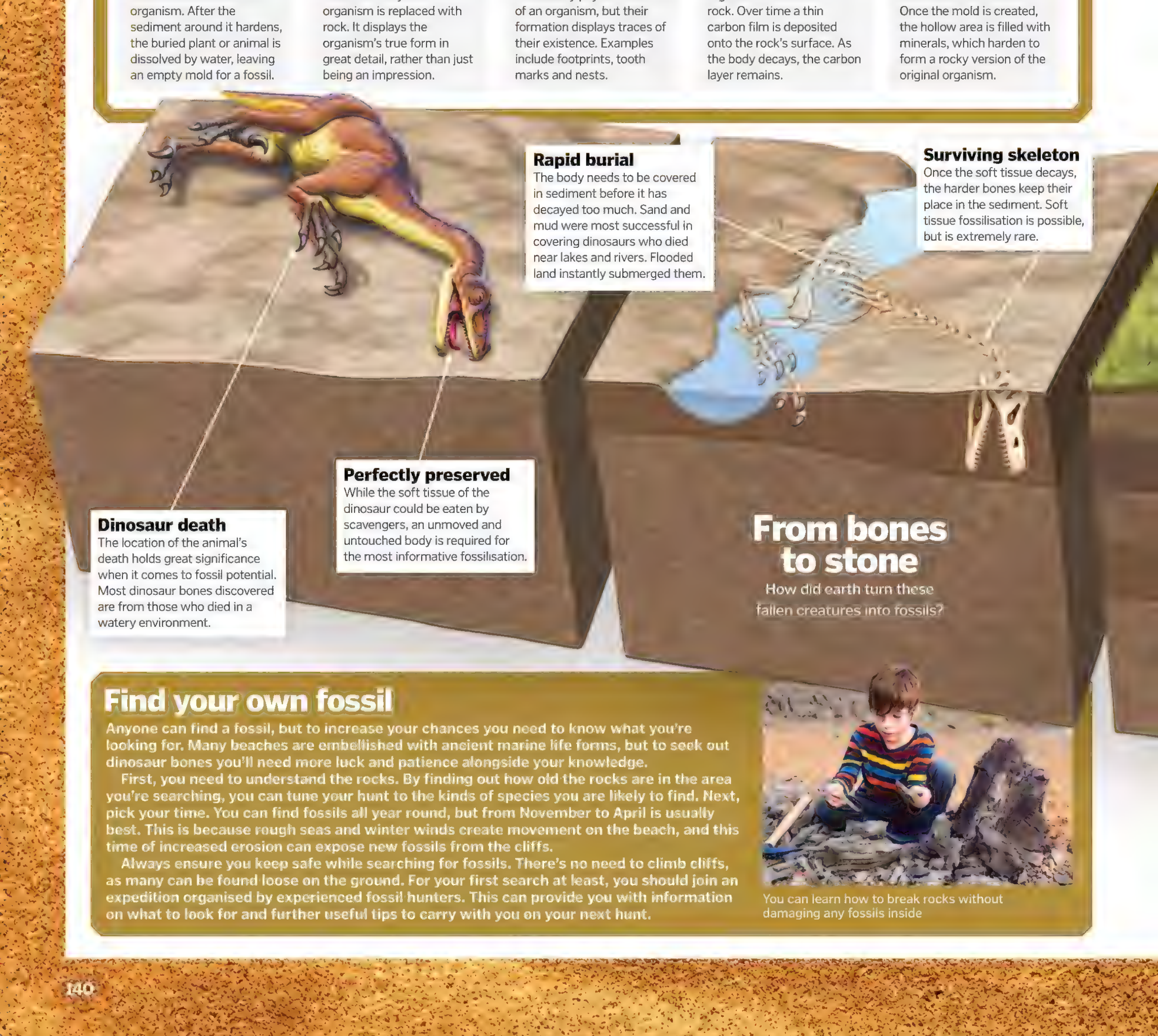
True form
These fossils are created when the body of an organism is replaced with rock. It displays the organism's true form in great detail, rather than just being an impression.

Trace
Trace fossils aren't necessarily physical remains of an organism, but their formation displays traces of their existence. Examples include footprints, tooth marks and nests.



Carbonised
Created when a dead organism is buried on flat rock. Over time a thin carbon film is deposited onto the rock's surface. As the body decays, the carbon layer remains.

Cast
Cast fossils are more advanced mold fossils. Once the mold is created, the hollow area is filled with minerals, which harden to form a rocky version of the original organism.



Rapid burial
The body needs to be covered in sediment before it has decayed too much. Sand and mud were most successful in covering dinosaurs who died near lakes and rivers. Flooded land instantly submerged them.

Surviving skeleton
Once the soft tissue decays, the harder bones keep their place in the sediment. Soft tissue fossilisation is possible, but is extremely rare.

Perfectly preserved
While the soft tissue of the dinosaur could be eaten by scavengers, an unmoved and untouched body is required for the most informative fossilisation.

Dinosaur death
The location of the animal's death holds great significance when it comes to fossil potential. Most dinosaur bones discovered are from those who died in a watery environment.

From bones to stone
How did earth turn these fallen creatures into fossils?

Find your own fossil

Anyone can find a fossil, but to increase your chances you need to know what you're looking for. Many beaches are embellished with ancient marine life forms, but to seek out dinosaur bones you'll need more luck and patience alongside your knowledge.

First, you need to understand the rocks. By finding out how old the rocks are in the area you're searching, you can tune your hunt to the kinds of species you are likely to find. Next, pick your time. You can find fossils all year round, but from November to April is usually best. This is because rough seas and winter winds create movement on the beach, and this time of increased erosion can expose new fossils from the cliffs.

Always ensure you keep safe while searching for fossils. There's no need to climb cliffs, as many can be found loose on the ground. For your first search at least, you should join an expedition organised by experienced fossil hunters. This can provide you with information on what to look for and further useful tips to carry with you on your next hunt.

You can learn how to break rocks without damaging any fossils inside

to be retrieved before the conditions above the ground erode or damage it and render it unrecognisable. The reason that the number of finds has increased in recent years is in large part due to our expanding knowledge of the dinosaurs and the evolving technology that helps us to study them.

More people are out looking for dinosaur fossils today than ever before. We now know where the best places to look are, what kind of shapes the eye should be drawn to and the best times of year to search. Knowing where to look and what to look for has increased the success of beachcombing and geological digs.

> "Sometimes it simply means being in the right place at the right time"

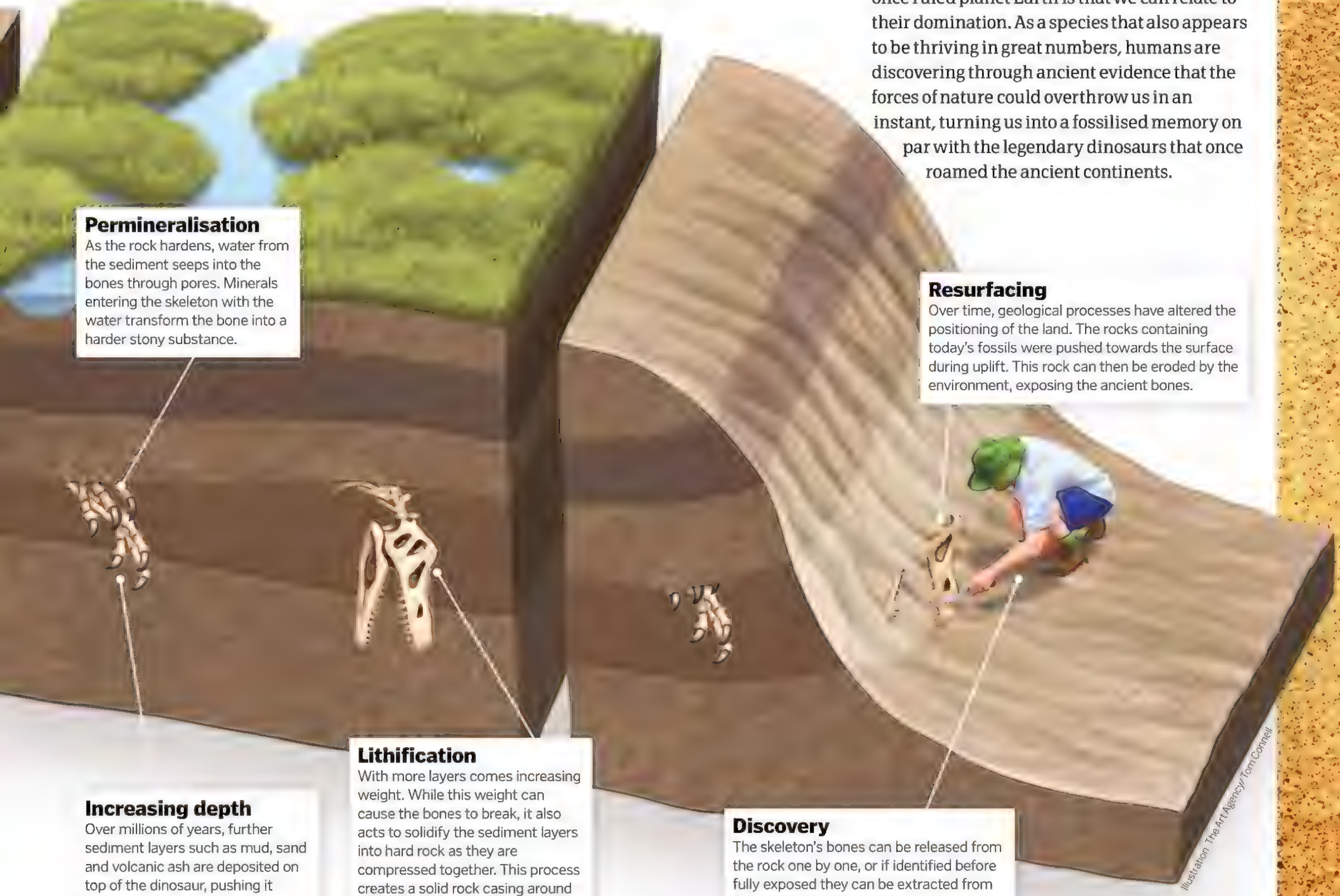
Although learning from previous finds enhances our understanding of what to look for next time, new species are often found in the least expected locations. One of the most recent dinosaur revelations was plucked from a British beach on the Isle of Wight last year, and after thorough research it was revealed to be a new species this summer.

This new species was retrieved from an unusual sediment type where the average fossil collector wouldn't think to search, showing that repeating methods of past finds doesn't always provide new results. This acts as an example that maybe the best way to search for something you don't know exists yet is not to search in conventional places at all. Sometimes the most notable fossils will find you.

The world of the dinosaurs seems so distant, but with every new species found we get closer to it. As our advancing knowledge of the relationship between each species grows, we have learned that dinosaur traits have been carried into the present day – and not just in their fossilised form. Modern birds actually originated in the Mesozoic Era, evolving from the theropod dinosaurs. Members of this group ranged drastically from the immense *Tyrannosaurus rex* to tiny bird-like creatures.

The sheer diversity between dinosaur species that have been discovered so far demonstrates just how much these animals evolved during their time on our planet. With every fossil that palaeontologists research, more pieces are added to the evolutionary story of the dinosaurs.

Perhaps one of the reasons humans have become so infatuated with these beasts that once ruled planet Earth is that we can relate to their domination. As a species that also appears to be thriving in great numbers, humans are discovering through ancient evidence that the forces of nature could overthrow us in an instant, turning us into a fossilised memory on par with the legendary dinosaurs that once roamed the ancient continents.



Permineralisation
As the rock hardens, water from the sediment seeps into the bones through pores. Minerals entering the skeleton with the water transform the bone into a harder stony substance.

Resurfacing
Over time, geological processes have altered the positioning of the land. The rocks containing today's fossils were pushed towards the surface during uplift. This rock can then be eroded by the environment, exposing the ancient bones.

Increasing depth
Over millions of years, further sediment layers such as mud, sand and volcanic ash are deposited on top of the dinosaur, pushing it further below the surface.

Lithification
With more layers comes increasing weight. While this weight can cause the bones to break, it also acts to solidify the sediment layers into hard rock as they are compressed together. This process creates a solid rock casing around the dinosaur remnants.

Discovery
The skeleton's bones can be released from the rock one by one, or if identified before fully exposed they can be extracted from the rock by palaeontologists.

Illustration: The Art Agency/ Tom Connell

A new dinosaur

Discover how a new species was uncovered

It was recently revealed that four dinosaur bones, found last year on the Isle of Wight, England, are those of an entirely new dinosaur species. Since October 2019 these bones have been held at the University of Southampton, where palaeontologists have been hard at work trying to discover what animal they belong to. They soon realised, after comparing each minute detail to a computer database, that this species had never been seen before.

Named the *Vectaerovenator inopinatus*, it is a member of the theropod family of dinosaurs, making it a close relative of the *Tyrannosaurus rex*. Its given name sums up many of its discovered qualities.

'Inopinatus' means unexpected. What made these bones particularly interesting to palaeontologists is that they were found in the lower greensand. This is a marine sediment which is a rare location for dinosaur fossils and a likely reason why the species had not been located before.

Neil Gostling, who supervised the study, said: "The Isle of Wight is the best place to find dinosaurs in Europe, but usually these finds are a terrestrial deposit. It is exciting because greensand is 116 million years old, and we have a poor understanding of European dinosaurs in this time period."

'Aero', which is incorporated into the new species' name, means air in Latin, and refers to the hollow properties of the four bones studied. They have large holes which would have been extensions of lung tissue for gas exchange.

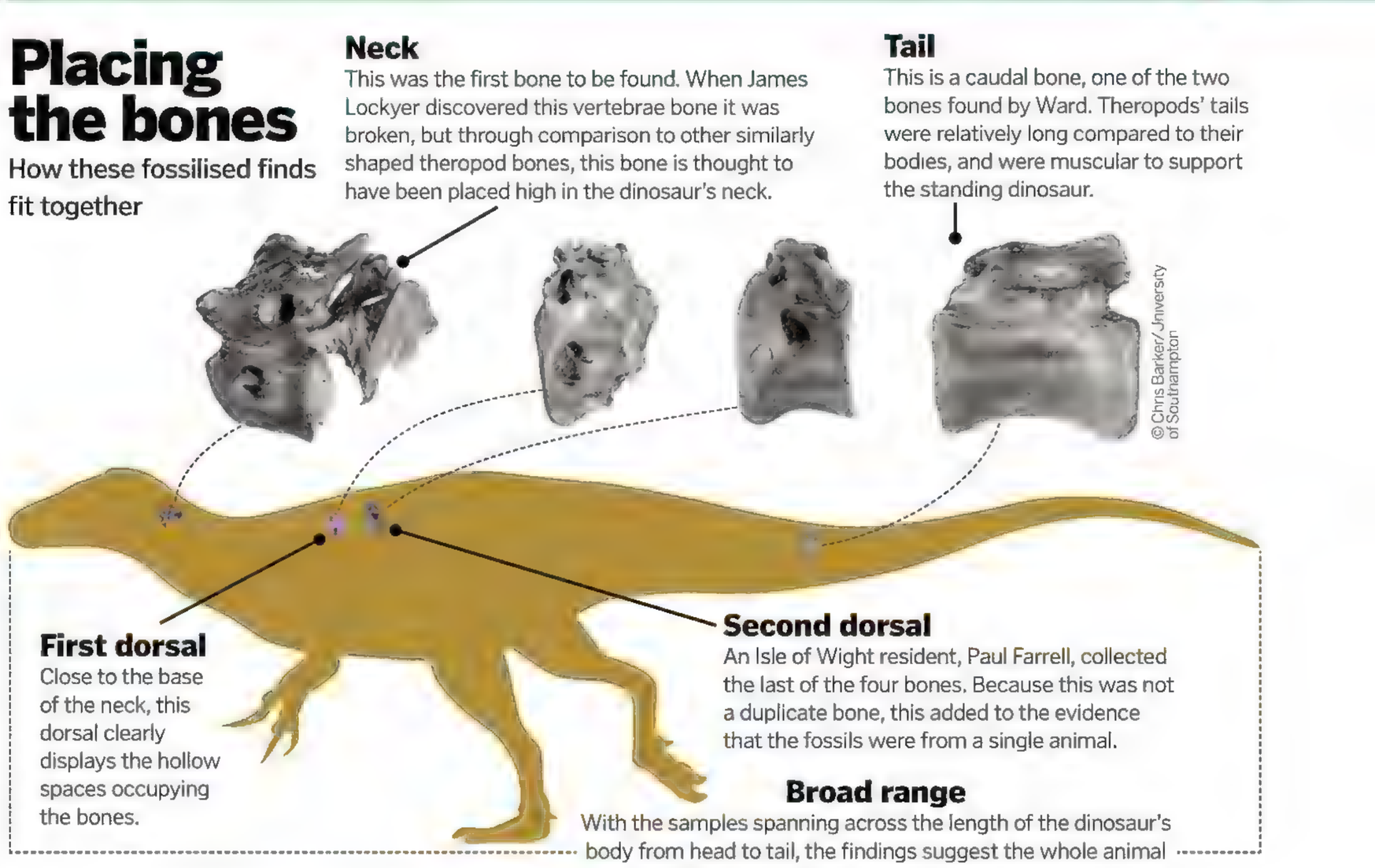
"This is a very efficient way of getting oxygen into the body," Gostling said, "which some other theropods have as well. [The four fossils] don't feel like rock because they're almost hollow."

Despite only four bones being studied from this dinosaur, the university has already determined specific details about this ancient creature. Since the release of the findings another two bones from the same species have been handed in, and the researchers hope to soon reveal further information about it.

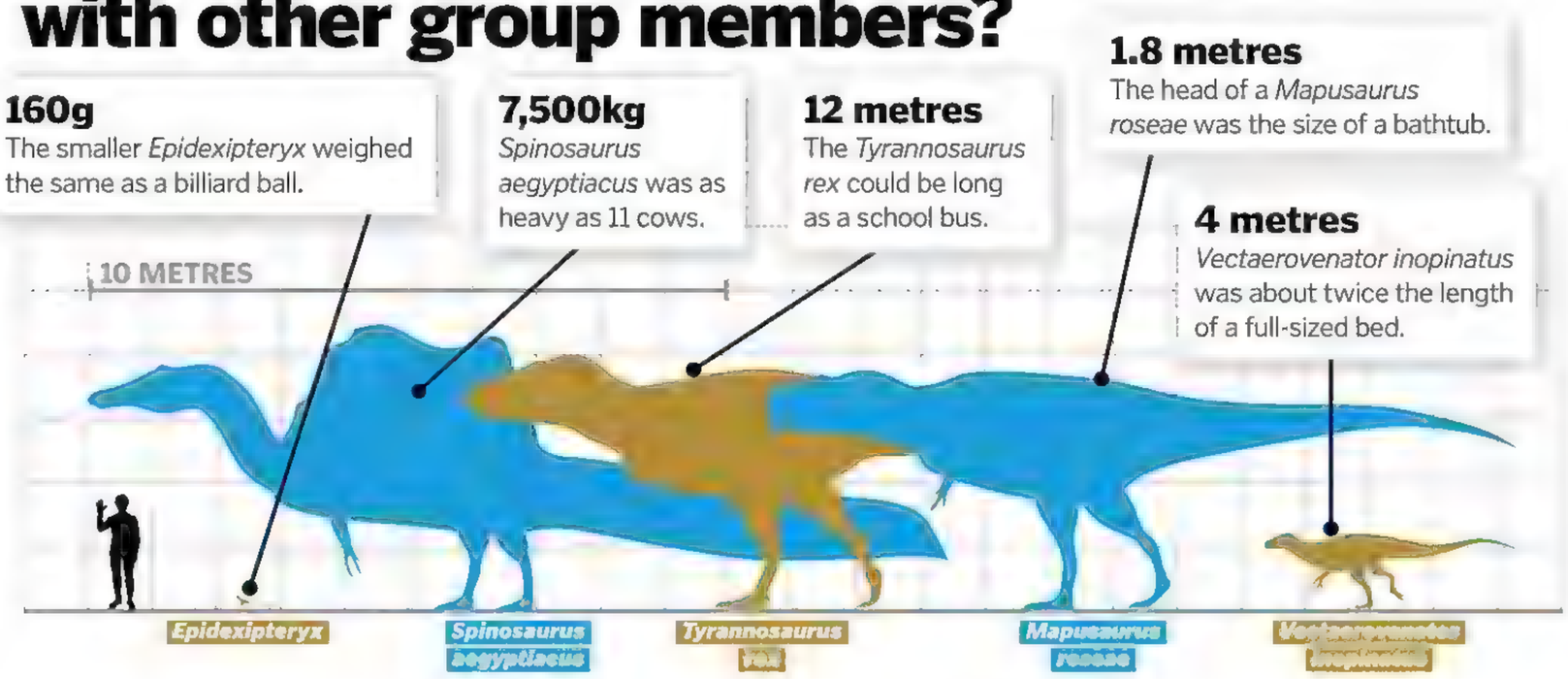
© Trudie Wilson

Placing the bones

How these fossilised finds fit together

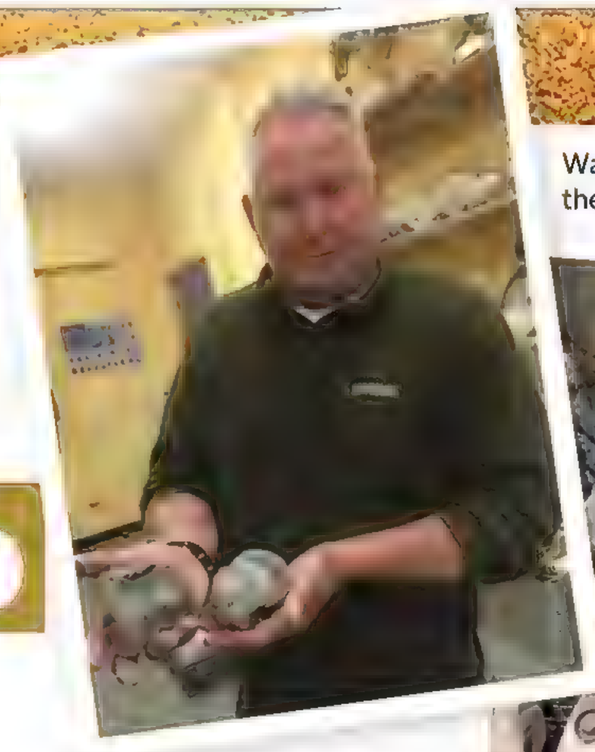


How does the new theropod compare with other group members?



Q&A

Fossil hunters who hit the jackpot



Lockyer found a bone from the neck

Ward discovered two of the dinosaur's bones

Robin Ward and James Lockyer weren't expecting to find a new dinosaur species when they visited the Isle of Wight last year. In March 2019 Lockyer discovered one of the dinosaur's bones, and Ward found two more in May. The fourth bone involved in the study of this species was collected by Paul Farrell.

What brought you to the Isle of Wight?

RW: I have been to the Isle of Wight a few times, but it was my daughter who chose to go there this time, as it was her tenth birthday. When we arrived we were too early to check into the hotel, so we decided to go fossil hunting on Shanklin Beach while we waited.

JL: I have been fossil hunting for the last 10 to 15 years and went to the Isle of Wight because it is an area with rapid erosion of the cliffs. Because of that, it's a good place to find fossils.

How did you come across the bones?

RW: As I searched the rocky area, I knew a find was possible because there had just been a high tide, which could uncover fossils from the sand. When I came across the first one on the floor, I videoed myself picking it up and posted it online. I knew it was from a dinosaur. I found the second just five minutes later, about eight feet [2.4 metres] away. I was so chuffed I did a bit of a jig on the beach. It's the find of a lifetime.

JL: I was told I wouldn't find much on Shanklin Beach, but I like to look in areas where others don't. I began searching the foreshore among the rocks and there it was – half a vertebrae – popping out the rocky substrate. I went to wash it in the sea and saw that it had a nice shape to it.

"I was told I wouldn't find much on Shanklin Beach"

When were you made aware of the significance of your find?

RW: The first was clearly a dinosaur bone. The second one was a different shape, but looked like the same rock. They were so close I thought they had to be from the same dinosaur, and they were.

Two days later I went to the Dinosaur Isle museum to see what I had found. The palaeontologists' eyes lit up as soon as they saw them. They couldn't find anything like them in their exhibit. It was only after they had been properly researched that I found out it was a new species.

JL: I knew I had found a vertebrae as I have an interest in archaeology and I am quite good at spotting bones. I also knew it was a fossil.

At the museum, they were very interested in it but weren't sure what it was. They said it was the best find of the year so far. But it was when they got involved with the University of Southampton that things got more interesting and they established what it really was.

How does it feel to be linked to the discovery of this species?

RW: It's like winning the lottery. I fossil hunt all the time. Whenever I have five minutes I'll be looking through some gravel, but a dinosaur bone is the ultimate find. Gifting the bones to the museum was a bit like winning the lottery and then giving your money away, but if I hadn't they would only have had half of the bones they had to research, and I wouldn't know they were something special.

JL: It was nice to find it in the first place, but as time went on and I learned more about it, it got even more exciting. I think it's incredible that the university has the technology to identify something that we didn't even know existed. In a lifetime it is nice to have one notable find. To me all fossils are interesting to find, but to have my name against this find is exciting.

What do you like about fossil hunting?

RW: When you crack open a stone, most of the time there will be nothing in it, but when you do find something, you're the first person on Earth who's ever seen it. That's such a good feeling in itself.

JL: Ever since I was young I've liked searching. I was always digging holes in the garden. I didn't always know what I was collecting until I started fossil hunting more seriously and began learning about the geology of what I was finding. The best bit is not knowing what you're going to find. A lot of the time you don't find anything, so when you do there is a thrill.

How does this dinosaur compare to your previous finds?

RW: This was my best find in the fact that it is a new species. I have also got an ichthyosaur skull, which was a cool find. That was a reptile that swam in the sea a bit like a dolphin.

I've had many less successful searches. Once I found a shell which was probably 400 million years old. I threw it over to my son to have a look and he chucked it straight into the sea, thinking it was just a stone. No one will see that ever again.

JL: I've found marine reptile bones and various other fossil types. One of my personal favourites has been fossilised seeds. They are fascinating because they look like the seeds we have today but they are millions of years old. It's quite incredible to think that would have been the life of a new plant.

Five fantastic finds

Discovered fossils of some of the most mesmerising moments in prehistory

1 FOREVER FIGHTING
Mongolia 1971

When these dinosaurs began this fight around 80 million years ago, they probably didn't know they were fighting to the death... of them both. This fossil of a Velociraptor and a Protoceratops was discovered in a tangled scrap within the Gobi Desert's sandstone cliffs. The Velociraptor has its foot claw in the neck of the Proceratops, which is biting back at its opponent's arm. It is believed that a sudden sand flow buried them mid-fight, freezing the moment.

2 LARGEST *T. REX*
Canada 1991

The *Tyrannosaurus rex* is probably the world's most well-known dinosaur. Their towering stature contrasts comically with their dinky arms. After more than 20 years, research of Scotty brought this enormous species to a new level. At 13 metres long, his leg bones suggest that he would have carried a weight of 8,870 kilograms. This makes him the largest of his kind to be found.

© Kumiko

3 MOST PRESERVED DINOSAUR
Canada 2011

When miner Shawn Funk began digging in the Suncor Millennium Mine in Alberta, Canada, he wasn't expecting to unearth a 112-million-year-old armoured dinosaur. While this was impressive enough, this nodosaur had been preserved to keep the exact shape it flaunted while it roamed Earth. Because of its rapid sea burial, the dinosaur was below ground before it had time to begin decaying. The rock solidified around each scale, imprinting a detailed design on the petrified remains. The fossil provides scientists with extraordinary detail of the animal's skin, scale patterns and overall shape.

4 BIRD-LIKE BEHAVIOUR
Mongolia 1994

This small theropod, *Citipati osmolskae*, was fossilised while protecting its eggs between 83 and 66 million years ago. Spread out across its nest, just as birds often do, this find confirmed that nesting is an ancient behaviour. Uncovered from the sand of the Gobi Desert, the positioning of the body over the nest made it clear to palaeontologists that this species was guarding its young. This was the first substantial evidence showing this behaviour.

© Dinoguy2/Wikimedia Commons

5 DINO EMBRYOS
China 2017

Finding dinosaur eggs is relatively rare, as many were soft-shelled and unlikely to become fossils. But in an even rarer case, palaeontologists in northwest China stumbled across over 200 dinosaur eggs. Within these eggs, 16 preserved embryos were found. The huge number of eggs are thought to be in the same area because the land was continuously flooded, but the dinosaurs used the same nesting site over a period of time.

Inside a palaeontologist's tool kit

What do you need to access hidden fossils?

1 Chisel
Dinosaur fossils are often found within rocks. Using a chisel and a hammer, rocks can be chipped away to reveal the inside.

2 Walkie-talkie
Some of the best finds are in extremely remote locations. If a group of fossil hunters splits up, contact with a designated base camp can be essential.

3 GPS
Keeping a record of where you are while looking for dinosaurs adds an element of safety. It is also ideal for documenting the exact location of the find.

4 Pointed-tip rock hammer
This tool is designed for use on hard rock. The flat end is used to crack open the rock and see inside without damaging any potential fossils within. The pointed end is used to dig a sample of the rock to analyse its mineral components.

5 Small probes and chisels
Accessing fossils can be a delicate procedure, requiring these small utensils. Fine-pointed picks work to uncover small fossils.

6 Dust brush
If fossils are covered in rock debris and dirt, soft brushes are a perfect way to reveal them without causing damage.

7 Swiss army knife
Compact and containing an assortment of small tools for every job, swiss army knives can be used to manipulate the rock on small samples.

8 Vinac
This solution of polyvinyl acetate adds a preservative coating to fossil finds. To stabilise dinosaur bones and stop them from breaking, they can be coated in vinac. The thin solution can be easily removed in a fossil laboratory later on.

9 Pens and bags
Fossils aren't always uncovered in one piece, with many found fragment by fragment. Plastic bags can hold pieces of a fossil together while you can use a pen to document how and where they were found, for future reference.

10 Measuring tape
Recording plenty of information about a fossil and its finding place is useful when it comes to researching the find. Measuring the distance between two found fossils can be useful in determining the likelihood that the bones are from the same animal.

"Using a chisel and a hammer, rocks can be chipped away to reveal the inside"

Extinct behaviour

Fossils can provide incredible details about dinosaurs' anatomy and what they looked like, but what can they teach us about their lifestyles? These limited remains don't tell us everything, often leaving scientists guessing about the colour of their scales and the sound of their roars. But when it comes to their behaviour, palaeontologists can analyse data from the fossils' locations and shapes of their features to link them to possible behaviours.

The size and shape of a dinosaur's teeth would have adapted to suit their diet, with long, sharp teeth indicating an animal that feasted on the meat of other animals. In some of the rarest fossils the contents of the stomach have been preserved – an even clearer answer to what was eaten.

When there is a combination of features all suiting a particular behaviour, this cements the hypothesis further towards certainty. Dromaeosaurs can find clues in the structure of claws, fingers, wrists, joints and backbones that suggest a dinosaur's ability to run. When all of these features are present, this abundance of data paints a likely picture.

Inside the White House bunker

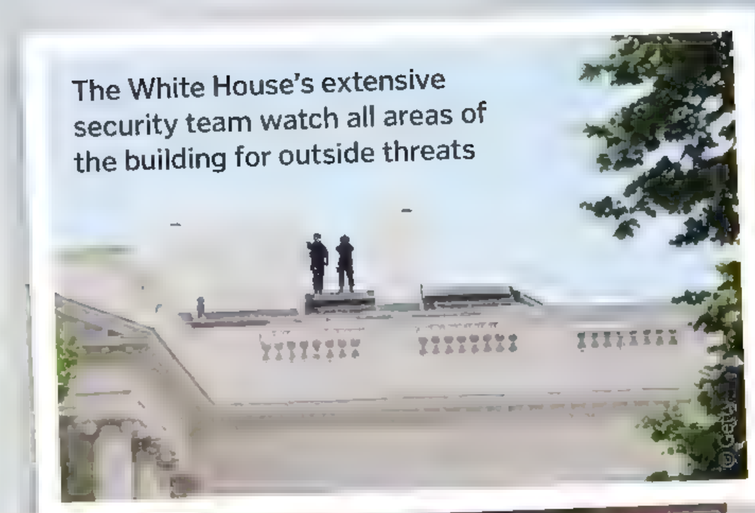
Words by **Ailsa Harvey**

Where can the president go for ultimate protection?

Looking at the White House, it's easy to become envious of the lifestyle that comes with being the president of the United States of America. But this role comes with a target on your back. The president is unable to travel anywhere, step outside their house or even sleep in their own bed without security technology and personal guards.

In 2020, Donald Trump disappeared from the White House building as protests outside intensified. But where did he go? The answer lies beneath the East Wing of this mighty home, in the form of an underground bunker.

Built during World War II for President Franklin D. Roosevelt, the first White House bunker was deemed essential following the 1941 Pearl Harbour attack. Since then a more modern and secure version has replaced it. An evacuation to the safety of the bunker was made by senior officials during the 9/11 attacks on the World Trade Center. Before this disaster the preferred option was always to escort the president out of the area before retreating below ground. However, in this case it became a concern that there wouldn't be enough warning given of an attack to execute this escape plan. Predictably, many of the details of this bunker are top secret, but here's what is known about this mysterious hideaway.



The White House's extensive security team watch all areas of the building for outside threats

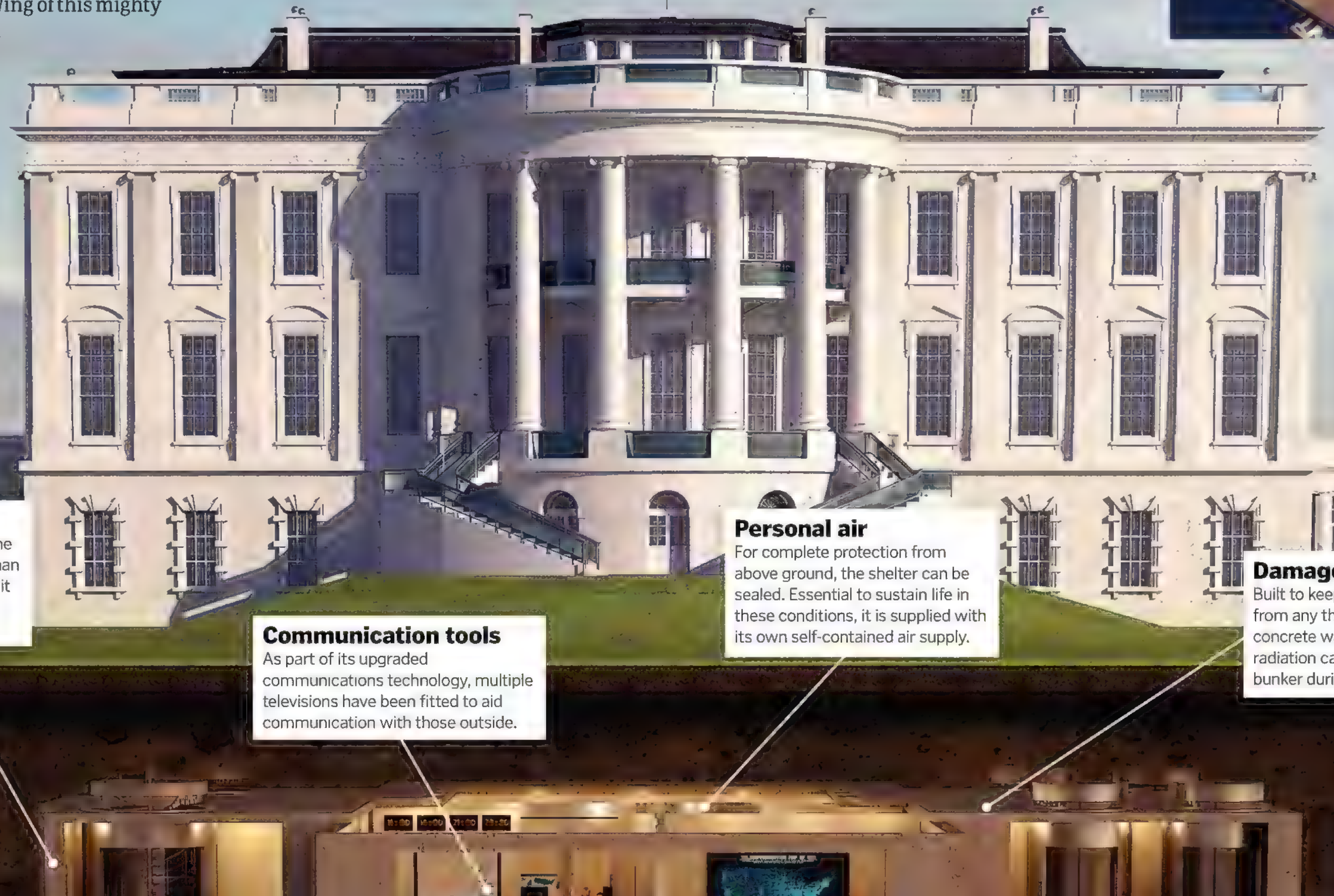
© Getty

© The US National Archives

On 11 September 2001, senior staff at the White House meet in the underground Emergency Operations Center

Subterranean living

The underground retreat needs to keep occupants secure, happy and healthy for a potentially lengthy stay

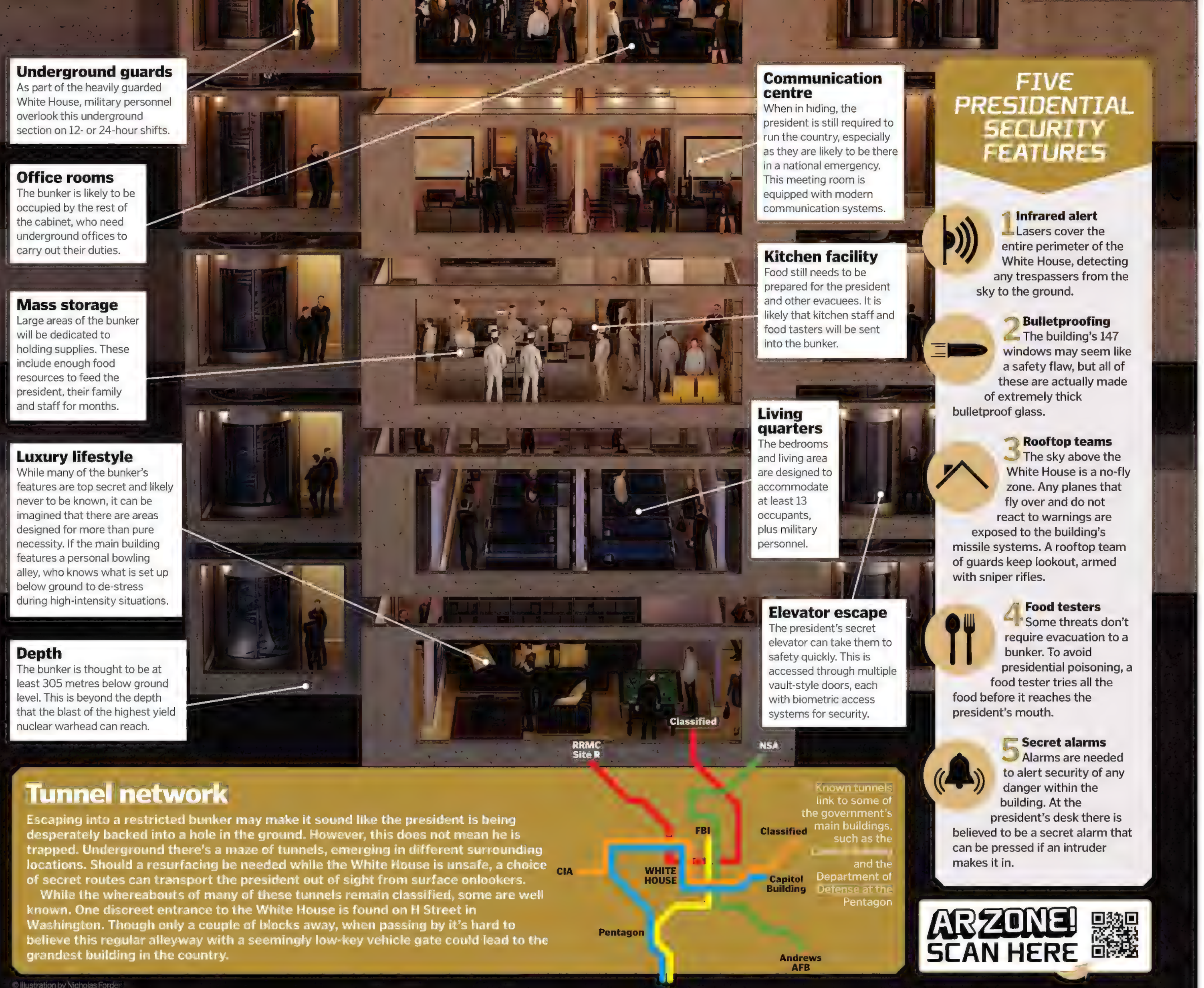


Multistorey
The top-secret second home of the president is bigger than most people's first home – it is said to have five floors below the ground.

Communication tools
As part of its upgraded communications technology, multiple televisions have been fitted to aid communication with those outside.

Personal air
For complete protection from above ground, the shelter can be sealed. Essential to sustain life in these conditions, it is supplied with its own self-contained air supply.

Damage-proof
Built to keep the president safe from any threat, the thick concrete walls ensure no radiation can reach inside the bunker during a nuclear attack.



Underground guards
As part of the heavily guarded White House, military personnel overlook this underground section on 12- or 24-hour shifts.

Office rooms
The bunker is likely to be occupied by the rest of the cabinet, who need underground offices to carry out their duties.

Mass storage
Large areas of the bunker will be dedicated to holding supplies. These include enough food resources to feed the president, their family and staff for months.

Luxury lifestyle
While many of the bunker's features are top secret and likely never to be known, it can be imagined that there are areas designed for more than pure necessity. If the main building features a personal bowling alley, who knows what is set up below ground to de-stress during high-intensity situations.

Depth
The bunker is thought to be at least 305 metres below ground level. This is beyond the depth that the blast of the highest yield nuclear warhead can reach.

Communication centre
When in hiding, the president is still required to run the country, especially as they are likely to be there in a national emergency. This meeting room is equipped with modern communication systems.

Kitchen facility
Food still needs to be prepared for the president and other evacuees. It is likely that kitchen staff and food tasters will be sent into the bunker.

Living quarters
The bedrooms and living area are designed to accommodate at least 13 occupants, plus military personnel.

Elevator escape
The president's secret elevator can take them to safety quickly. This is accessed through multiple vault-style doors, each with biometric access systems for security.

FIVE PRESIDENTIAL SECURITY FEATURES

1 Infrared alert
Lasers cover the entire perimeter of the White House, detecting any trespassers from the sky to the ground.

2 Bulletproofing
The building's 147 windows may seem like a safety flaw, but all of these are actually made of extremely thick bulletproof glass.

3 Rooftop teams
The sky above the White House is a no-fly zone. Any planes that fly over and do not react to warnings are exposed to the building's missile systems. A rooftop team of guards keep lookout, armed with sniper rifles.

4 Food testers
Some threats don't require evacuation to a bunker. To avoid presidential poisoning, a food tester tries all the food before it reaches the president's mouth.

5 Secret alarms
Alarms are needed to alert security of any danger within the building. At the president's desk there is believed to be a secret alarm that can be pressed if an intruder makes it in.

Tunnel network

Escaping into a restricted bunker may make it sound like the president is being desperately backed into a hole in the ground. However, this does not mean he is trapped. Underground there's a maze of tunnels, emerging in different surrounding locations. Should a resurfacing be needed while the White House is unsafe, a choice of secret routes can transport the president out of sight from surface onlookers.

While the whereabouts of many of these tunnels remain classified, some are well known. One discreet entrance to the White House is found on H Street in Washington. Though only a couple of blocks away, when passing by it's hard to believe this regular alleyway with a seemingly low-key vehicle gate could lead to the grandest building in the country.

Known tunnels link to some of the government's main buildings, such as the [redacted] and the Department of Defense at the Pentagon

AR ZONE! SCAN HERE

© Illustration by Nicholas Forder

DID YOU KNOW? During WWII, President Roosevelt secretly hid in a mountain bunker retreat in Maryland

Discover the wonder of Egyptian mummification as we unravel the secrets of these carefully preserved corpses

© Bjørn Christian Tørrissen

Mummies unwrapped

Mummification was an embalming process undertaken by the ancient Egyptians. They believed that by preserving a body, its soul could live on in the afterlife. Embalmers offered various packages, which included a basic, standard and luxury version. Even so, it was only the rich that could afford to mummify their dead and thereafter place them in an elaborate tomb. Ordinary civilians were buried in pit graves, and some of these bodies were naturally dried.

Mummification was an elaborate and lengthy process that took 70 days. Violation of the body was abhorred, however, so the first incision performed on the corpse was made by a 'scapegoat', who was then ritually stoned and chased from the embalming chamber.

Afterwards the intestines, lungs, stomach and liver were removed – these were mummified and placed in special containers called canopic jars. The brain was pulverised with a long, narrow instrument and drained through the nose or the back of the skull. The heart, which was then known as the seat of learning, was left inside the body. During the mummification process the priests would venerate the dead; they would light incense, recite prayers and invoke aid and protection from ancient Egyptian gods. Once cleansed, the body was then ready to be dried.

The ancient Egyptians placed the body in natron salts, which absorbed all its moisture. After a period of 40 days it was removed and packed with herbs, oils and spices, which were known to cleanse and preserve the cavities. If extra body parts were needed the corpse was equipped with false wooden limbs, or eyes made of obsidian. It was then ready for bandaging. Each limb was carefully tended to. Fingers and toes were treated individually, and golden caps were placed on the nails. In order to protect it, a large number of amulets were left on specific parts of the body. Often garlands of leaves or berries, which were thought to have rejuvenating properties, were placed around the neck. The hair was dressed with oils and jewellery. Due to heat and lice the ancient Egyptians shaved their heads, so elaborate wigs – which were made of human hair – were placed on the deceased. Make-up was applied, and the body was dressed in fine clothes and adornments. While women were buried with combs and pottery, men were armed with daggers or swords. These were placed either on the body or within the wrappings.

At the beginning of the 20th century, Egyptology was in its infancy. Many early excavators ignored human remains. The first archaeologists were more interested in treasure than mummies, and even the body of Tutankhamun was subjected to trauma. Although Howard Carter was a brilliant excavator, he couldn't have imagined the

wonders that the dead could reveal. Nor did he envisage that innovations in science would enable us to make important new discoveries about ancient Egyptian mummies. Despite this, the world was now fascinated. In Victorian times the unwrapping of an Egyptian mummy – which often took place in affluent drawing rooms – would be followed by tea, cake and polite conversation.

Thankfully times have changed, and the first scientific unwrapping of a mummy took place in Manchester when Margaret Murray examined the two brothers, Khnum-Nakht and Nekht-Ankh, in 1908. Manchester continues its strong association with the scientific study of mummies. It is here that Professor Rosalie David conducted many innovative investigations into ancient diseases. In 1979 she established the International Mummy Database, which employs endoscopy and serological studies, X-ray examinations and MRI scans. Perhaps the most important investigation into ancient mummies was undertaken in Paris between 1976 and 1977, when the mummy of Ramesses II was met at Orly Airport and treated like a visiting head of state. A team of over 100 scientists, including botanists, microbiologists and anthropologists, worked on his body and published startling new evidence about mummification techniques.

Examinations that employ DNA sampling are now used in mummy studies. While the practice is still limited, it can enable Egyptologists to identify, establish and study family groups. We are now able to shed light on the everyday life of the ancient Egyptians, going on to analyse dental hygiene, hair dyes and make-up. When examining mummies we are now able to study textiles, jewellery, oils and even head lice – the oldest 'nits' in the world were found on a Manchester mummy. From these examinations we can learn a great deal about the diseases, afflictions and the general aches and pains of all classes of people, and we can even identify trauma wounds, arthritis and polio. With the invention of new scanning techniques, the destructive process of 'unwrapping' a mummy is now a thing of the past. What remains constant, however, is that mummies continue to fascinate, excite and inspire us.

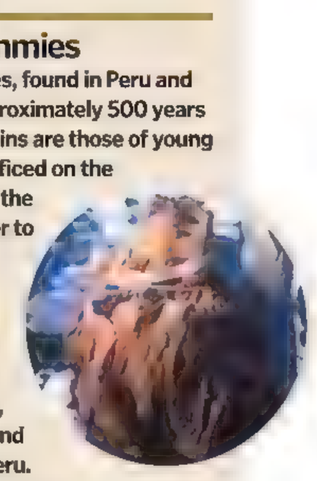

Modern technology such as CT scans can help to provide us with more information

© Science Photo Library

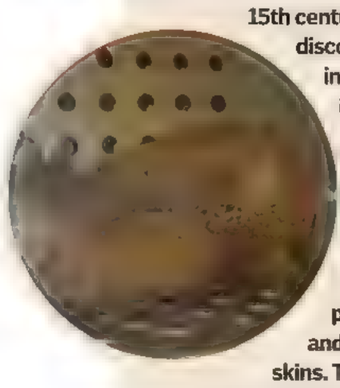
TYPES OF... MUMMIES AROUND THE WORLD

1 Ice mummies

Dated to Pazyryk culture, the Siberian Ice Maiden and her contemporaries were buried in the 5th century BCE. These mummies were buried with elaborate funerary equipment – in the case of the Ice Maiden there were six horses and a symbolic last meal. Her body is covered in a series of beautiful tattoos depicting mythical animals.



2 Mummies of the Canary Islands



The Guanche mummies were found on the Canary Islands in the 15th century, when they were discovered by Spanish invaders. Little is known about them – many were pulverised and used as medicinal powders. Dried in the Sun, the mummies were packed with sand and wrapped in animal skins. They were then placed on mummy boards and left in caves.

3 Inca mummies

Inca mummies, found in Peru and Chile, are approximately 500 years old. The remains are those of young children sacrificed on the mountains of the Andes in order to honour the gods. Other mummies include those known as the Chachapoyas, which are found in northern Peru. These mummies were mummified in the driest areas of the jungle.

4 Mummies of the Capuchin Catacombs

Dated between the late 16th and 20th centuries, the mummies of the Capuchin Catacombs of Palermo are magnificent examples of the art of embalming. Thousands of bodies were dried here in 'strainers' – cells that are situated in the passageways of the catacombs. After eight months they were removed and soaked in vinegar. Adults and children are placed on display in coffins, niches and on the walls.

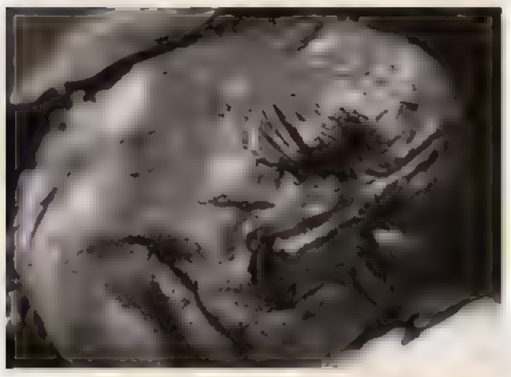
The well-preserved, naturally mummified body of a figure known as the 'Tollund Man'

"Only the rich could afford to mummify their dead and place them in an elaborate tomb"

King Tutankhamun, discovered by Howard Carter in 1922

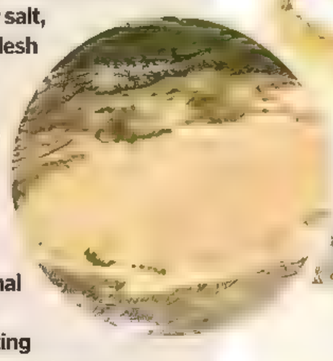
TYPES OF... NATURAL MUMMIES

1 Bog bodies
Waterlogged peat holds very little oxygen, and this means that the microorganisms that cause decomposition cannot survive. The acidity in the bog, along with sphagnum moss, also helps to preserve the body. While the skin, hair and internal organs are remarkably well preserved, the bones are softened. The body also begins to take on a dark, leathery appearance.



2 Self-mummification
Self-mummification was practised by the Sokushinbutsu, a group of Japanese Buddhist monks. For several years the monks would live on a diet of seeds and nuts and would drink the sap of the urushi tree, which would cause vomiting and loss of body mass. They would seal themselves in a tomb and die – if the body had mummified, it was regarded as a holy vessel.

3 Desiccation
When left in the open, water, insects and heat will rapidly destroy the body. If the body is buried in sand or salt, moisture in the flesh is absorbed and the corpse is preserved. More importantly, in the case of Egyptian mummies the removal of internal organs aids this process, preventing internal bloating and decay.



4 Ice mummies
Ice prevents decomposition of the body and inhibits the growth of bacteria. It also preserves pollen and dust grains. Ice is an excellent and effective agent, so ice mummies seem very lifelike. Their hair, eyelashes and body decorations are often astounding. Ice mummies have even been discovered with votive offerings and grave goods.

© South Tyrol Museum of Archaeology

Death chamber

We open the doors to the eerie and mysterious world of the embalming chamber to explain exactly how the process was performed

Although the House of the Dead was occupied by priests and their servants, it was also regarded as a place of dread. The sight or smell of the embalming chamber was a source of fear and repulsion.

Inside the House of the Dead there would often be a long queue of bodies waiting to be embalmed; they would be placed on sloping beds so that bodily fluids and blood would drain into vats. Insects, inexperienced workers and the heat could make the work difficult. The embalming process was an urgent and bloody activity – when rushed the embalmers often lost or severed limbs.

The morality of the morticians was also regarded with suspicion; they were often associated with robbery and corruption. However, morticians were also viewed as mystics and magicians, and a sense of secrecy surrounded their art of preparing the dead.

© Marie-Lan Nguyen

Tutankhamun's tomb remained sealed for more than 3,200 years

Coffins
Large, rectangular coffins were decorated with magical texts and painted eyes – believed to enable the dead to look out and survey their surroundings.

Preparation
Before a corpse could be embalmed, it was placed on a sloping table so bodily fluids could drain away.

Carrion birds
The Egyptians both revered and feared birds of prey. They were often depicted in funerary contexts and were associated with death on the battlefield.

Mourners and priests
A group of mourners and priests accompanied the body to the mortuary. After death, the body was quickly removed.

Reception area
The body was received in this small, holy vestibule. Here priests conducted prayers and spells to aid the deceased's journey into the next life.

© DK Images

FROM DEATH TO THE TOMBS

1. The death scene
This bed is a traditional funeral bier, or stand, which can be found among ancient Egyptian funerary equipment. It was designed to represent the body of a lion.

2. Embalmers at work
Several priests attended the body of the deceased; while some worked on the body, others would recite prayers and perform magical incantations.

3. Bandaging and anointing
Metres of linen bandages were used on mummies, where even each finger and toe was wrapped individually. The body was anointed in protective oils and resins.

4. Placement in coffin
Coffins differed over the years, both in style and decoration. The coffin was made of wood and gilded with precious metals. It was inscribed with magical texts.

Science of embalming

Funerary mask
The funerary mask was the last item placed on the mummy. It was often made of precious metal, preferably gold, in order to symbolise the regenerative force of the Sun.

Priest with Anubis mask
Anubis, the patron god of embalmers, was often depicted as a jackal. The Egyptians associated these animals with cemeteries. A priest would wear the Anubis mask when conducting funeral rites.

Priests with shaved heads
Priests shaved their heads as a symbol of cleanliness. They wore fine white linen kilts and simple reed sandals.

Table with embalming equipment
The priests used bronze tools in the mortuary. They employed tweezers, needles, hooks and knives during the mummification process.

Jars and ointments
Oils and salves were extremely valuable to the ancient Egyptians. They were used during mummification both to preserve the flesh and please the gods.

Incense burner
Incense was very important to the ancient Egyptians. It enhanced ritual purity and was thought to ward off evil.

Bandages and amulets
As each bandage was applied, the priest would pray and apply amulets to the body. Several hundred magical amulets can be found on a single mummy.

Jewellery
Jewellery had both decorative and religious importance. Necklaces, bracelets, earrings and rings were placed on the mummies of both males and females. This practice encouraged tomb robbery, however.

Funeral bier
The Egyptians associated the rising and setting Sun with two lion-headed deities. The funeral bier, with its lion-headed carvings, represented regeneration and rebirth.

A step-by-step look at the mummification process, from deathbed to the grandeur of the tomb

5. Mourners
The coffin was placed on a bier and dragged by oxen to the tomb. It was accompanied by priests, mourners and relatives.

6. Opening of the mouth
A priest, dressed in leopard skin, would 'open the mouth' of the deceased with an instrument called an adze. This allowed the spirit to fly free from the body.

7. Placing goods in the tomb
The ancient Egyptians believed that you could indeed 'take it with you'. Their tombs were filled with goods that were needed in the next world.

8. Priest leaving the tomb
At the culmination of the funerary rituals, the priest would leave the tomb. As he retreated, he would sweep away his footsteps from the dust.

9. Weighing of the heart
The heart is weighed before Osiris, god of the dead. If found wanting, the deceased would be devoured by a crocodile-headed monster.

GHOST TOWNS

These settlements were deserted and left to deteriorate. Come, explore them with us

Words by **Nikole Robinson**

There's something incredibly eerie about a town with no inhabitants, but there are many such places dotted around the world, left behind by those who once called them home. With no one remaining to maintain houses, buildings and roads, they slowly degrade over time, until one day rusted ruins and old stone structures are the only clues that humans once thrived there.

There are many reasons for an entire population to abandon a once-prosperous town, with floods, earthquakes, droughts or war driving people away for their own safety. Though both natural and human-made disasters can make an area uninhabitable, some settlements are left behind by choice when resources run out or the economy begins to collapse. Many of the world's ghost towns started out as mining communities, but once the ground stopped providing, there was nothing left to sustain them. Others were forsaken when the construction of a new road or railway bypassed the town, with people relocating to more accessible areas.

While many places are simply left to rot away, some of these neglected locations get a new lease of life as tourist attractions, acting as town-sized time capsules frozen at the point at which the occupants moved on. Those fleeing from disaster would often need to do so in a rush, so some buildings remain fully furnished, as if the people could come back at any moment.

Reasons for abandonment

Natural disaster
Unpredictable events such as floods, earthquakes, volcanic eruptions, droughts or coastal erosion can make an area unsafe to live in.

War
When people's homes become part of a warzone, the inhabitants need to flee to avoid being killed or injured.

Resources
If food or water is scarce, there's no way for a population to survive, while mining towns need to be prosperous to support people.

Economy
Inhabitants are likely to relocate if the local economy is in trouble, or if there are no jobs in an area.

Radiation
Humans can get sick or die when exposed to large doses of radiation, so it's not safe to live near a source.

Hashima Island

Location: Japan
Abandoned: 1974

This 16-acre island lies deserted off the coast of Nagasaki, Japan, with the concrete buildings and sea wall a stark contrast against the ocean. As Japan began to rapidly industrialise in the mid-19th century, the island was opened as an undersea coal mine. Bought by Mitsubishi, the company reclaimed more land from the sea and built tall, sturdy, grey buildings to house coal miners and their families. The island's population peaked at 5,259 in 1959, but soon Japan began to rely on petroleum for fuel instead, making coal redundant. The mine was closed in January 1974, and all inhabitants had abandoned the island by April. In 2009 the island was reopened to tourists, with boat tours ferrying people from the mainland to take in the untouched concrete buildings and former coal mine, which was declared a UNESCO World Heritage Site in 2015.

Source Wiki/Entry

Overgrown grass shows how nature is slowly reclaiming the seabound site

© Getty

A 1937 Chevrolet coupe rusts away in this Old West relic

© Getty

Bodie

Location: United States **Abandoned:** 1915

Following the California Gold Rush, prospectors first found the precious metal at this site in 1859, though the town didn't boom until around 18 years later. Growing rapidly to have a population of around 10,000 as miners flocked to make their fortune, by 1880 signs of decline began to show as men went to chase riches elsewhere. Never quite the same as it was in its prime, Bodie was referred to as a ghost town by 1915, though a few residents remained until the 1940s. Today it serves as a window into the Wild West, with its saloons and Methodist Church being among the most interesting attractions for visitors.

Happisburgh

Location: **UK**
Abandoned: **N/A**

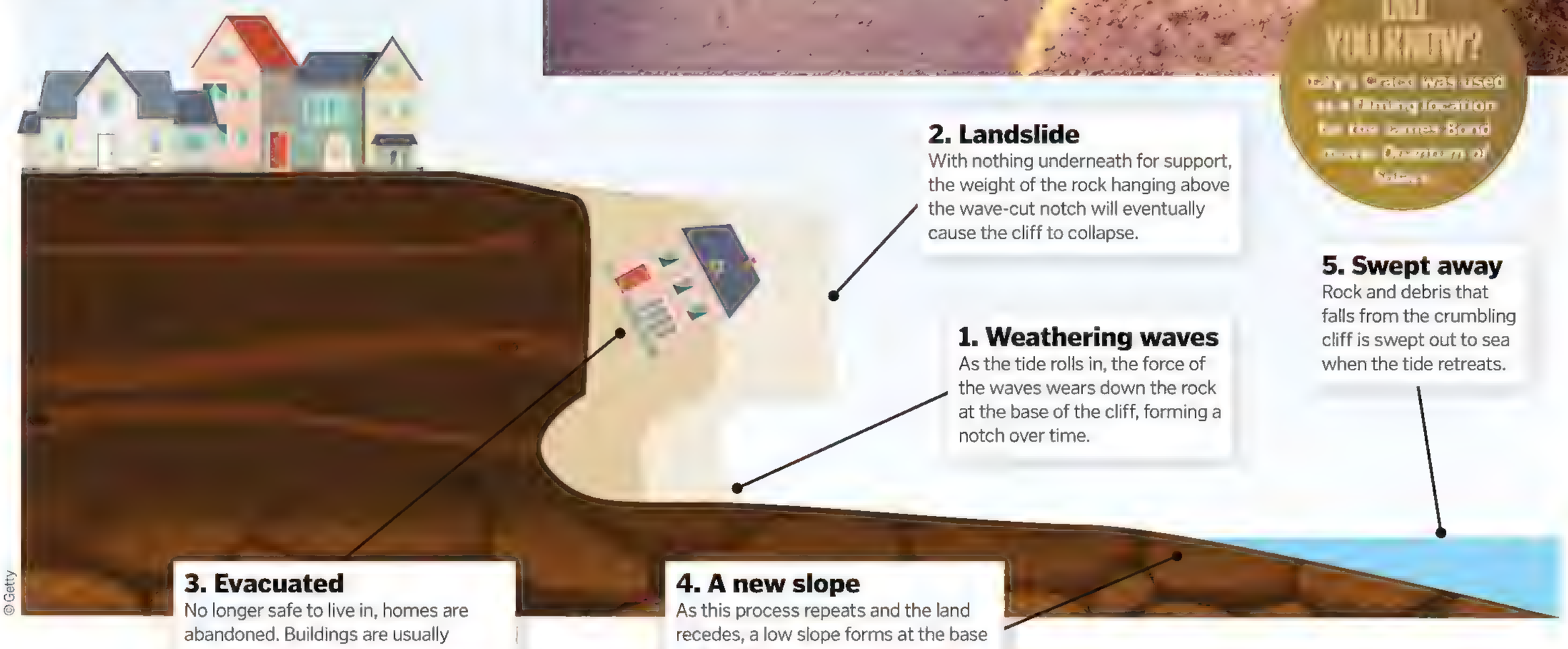
Though this village in Norfolk is inhabited and not technically a ghost town, erosion along the coast is forcing those living near the cliff's edge to evacuate before the land beneath them crumbles away, leaving their houses empty as they await their fate. Homes that sat six metres from the sea in 1998 now sit precariously on the edge, deserted by their previous owners. Though sea defences were built in 1959, and groynes added in 1968 to slow the process, the village will continue to shrink as it is battered by the sea.

The receding shoreline creeps closer to abandoned homes

© Getty

Coastal erosion

How the power of the waves cuts into cliffs



1. Weathering waves
As the tide rolls in, the force of the waves wears down the rock at the base of the cliff, forming a notch over time.

2. Landslide
With nothing underneath for support, the weight of the rock hanging above the wave-cut notch will eventually cause the cliff to collapse.

3. Evacuated
No longer safe to live in, homes are abandoned. Buildings are usually demolished to avoid dangerous debris.

4. A new slope
As this process repeats and the land recedes, a low slope forms at the base of the cliff, called a wave-cut platform.

5. Swept away
Rock and debris that falls from the crumbling cliff is swept out to sea when the tide retreats.

© Getty

DID YOU KNOW?

[illegible] was used as a filming location for the James Bond [illegible]

Craco

Location: **Italy** Abandoned: **1980**

[illegible]

Kayaköy

Location: Turkey
Abandoned: 1923

The massacre of this town's Greek inhabitants during World War I decimated much of its population. After the Greco-Turkish War broke out in 1919, a population exchange between Greece and Turkey meant that any survivors were forbidden from returning to their former homes and were forced to return to Greece.

Glenrio

Location: United States
Abandoned: 1975

This former railroad town sits right on the border between New Mexico and Texas along historic Route 66. Construction of Interstate 40 doomed the local economy when it bypassed the town completely. With less people passing through, it was no longer viable. Remains include an old motel, cafe, service station and post office.

Kolmanskop

Location: Namibia
Abandoned: 1956

It was built atop a diamond-rich area, with German-style architecture, but in 1928 many left to head 170 miles south for richer deposits. At the outbreak of World War II, the town was in decline due to the diamonds drying up. After its abandonment, geological shifts flooded buildings with desert sand, making reclamation unlikely.

An abandoned school littered with old gas masks

Pripyat is still unsafe to live in because of lingering radiation

Pripyat

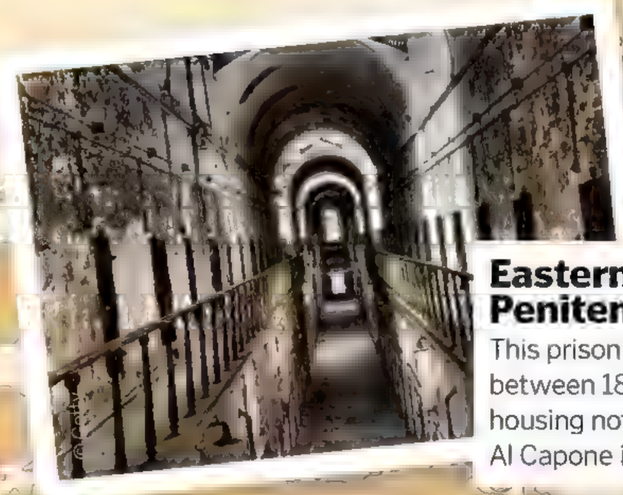
Location: Ukraine **Abandoned:** 1986

The meltdown at the Chernobyl Nuclear Power Plant on 26 April 1986 rendered the nearby city of Pripyat, which was built to house the plant's scientists and workers, unlivable because of the radioactive fallout from the disaster. Its 49,360 residents had to be evacuated quickly due to the danger posed by the plant, leaving their belongings behind as they ran for their lives. Though only 54 residents passed away after short-term exposure to radiation, many others suffered from acute radiation sickness.

An 18-mile exclusion zone around the plant was cordoned off by Ukrainian authorities, but radiation levels have dropped enough in recent years to allow former residents, urban explorers and dark tourists to visit for short periods of time. It will still be thousands of years before radiation levels have dropped to a safe level for human habitation.

DID YOU KNOW?

On 30 April 2020, a man was arrested for camping on Disney's Discovery Island.



Eastern State Penitentiary

This prison was operational between 1829 and 1971, once housing notorious gangster Al Capone in a lavish cell.

Oradour-sur-Glane

In June 1944, Nazi soldiers massacred the townsfolk and burned their homes. The ruins are preserved as a memorial to those lost.

Disney's Discovery Island

Disney closed this part of its Florida park in 1999, and its animal inhabitants were relocated to Disney's Animal Kingdom.

Plymouth, Montserrat

Called the Pompeii of the Caribbean, a series of volcanic eruptions between 1995 and 1997 buried the capital of Montserrat in ash.

Beelitz Military Hospital

This military hospital once housed soldiers from Germany and the Soviet Union, including a young Adolf Hitler during World War I.

Fordlândia

Built as a rubber plantation by Henry Ford, diseased trees and a worker's revolt were the downfall of this company town.

LEFT TO THE ELEMENTS

These human-made structures sit empty and desolate around the world

Pripyat amusement park
Due to have its grand opening on 1 May 1986, the meltdown at the plant left the iconic Ferris wheel and other rides to rust.

Varosha
When Turkey invaded Cyprus in 1974, 15,000 residents fled for their lives. Political unrest has made it impossible to return.

Ryugyong Hotel, Pyongyang
This pyramid-shaped hotel's opening has been delayed many times since construction began in 1987. It remains empty.

The Ruins, Talisay City
Once the home of a sugar baron, it was burned down during World War II to prevent invading Japanese forces from using it as a base.

How the slave trade ended

Why the British Empire stopped these harrowing transatlantic shipments and their human cargo

Safety net
The ship's crew made escape difficult by placing nets around the ship's perimeter: less slaves at the end of their voyage meant less profit.

Escape
The brutal conditions on board and the knowledge of their destination made many desperate to escape. Some would try to jump off the ships mid-voyage. Those who died during the trip were thrown overboard.

Slaves were often sent to work on tobacco, rice and cotton plantations, picking the luxury goods that they may have been sold for

Beginning in the 1500s, the slave trade saw millions abducted from their homes and shipped against their will to endure a life of manual labour and mistreatment. Mainly targeting Africa, people were transported across the Atlantic to America, where they would be auctioned.

Having been split from their families, people were forced aboard cramped and disease-ridden ships for months. Life at sea involved brutal physical and emotional abuse, with around 15 per cent dying on the journey. Some feared losing their lives on board, while others feared the lives they were sailing towards, and were force fed by crew as they tried to starve themselves. Objectified and sold in a foreign land in exchange for goods such as cotton, sugar, tobacco and ginger, how could such an unjust and profit-driven operation continue for centuries? And how was this entrenched and barbaric system eventually banned?

When Britain explored other countries, encountering diverse and unfamiliar civilisations, instead of embracing these new cultures, Britons were much more interested in the available land and the people they could utilise for economic gain. The attitudes to race at the time meant that the government allowed this unjust treatment of innocent people. Because the slave trade was legal, those who protested against it needed to find a way to reach those in power to bring about change. It took a combination of enslaved activists and distant onlookers to battle to bring these centuries of torment to a close. As slaves spoke out about their own experiences and those in parliament began to acknowledge the barbarous practices involved, the laws on the trading of people were revisited.

When slavery was first abolished, no more slave ships were allowed to set sail. But this didn't include freeing those who were already held as slaves. It wasn't until 1838 that all slaves in the British Empire were granted freedom. None of them were given any form of compensation for a lifetime of anguish and torture, while owners were paid by the government for the loss of each slave.

1562
John Hawkins captured 400 Africans in a violent conflict and traded them in the West Indies for pearls, ginger and sugar. He is the first known Englishman to have done this.

1713
The Treaty of Utrecht provided permission for Britain to import an unlimited number of slaves to the Spanish Caribbean.

1728
The First Maroon War took place in the British colony of Jamaica. This involved the retaliation of slaves who had managed to escape

1765
After making friends with Jonathan Strong, a slave who was being badly beaten, Granville Sharp began to challenge the British slave trade

1772
American Quaker John Wooiman arrived in England to ask Quakers there to join him in support of his anti-slavery campaign.

On board the slave ships

What was it like to travel as an item to be sold?

Women and children
Often separated from the men, women and children had slightly more space, but being nearer the deck made them targets for abuse from the crew.

Labour
Slaves were often forced onto the deck of the ship and made to exercise or carry out manual labour.

Ships' design
To endure 12-month round trips in changeable conditions, the large ships had many sails and a complex rigging system.

Below deck
Space was so cramped in the middle sections of the ship that people were forced to lie down or crouch so that everyone could fit.

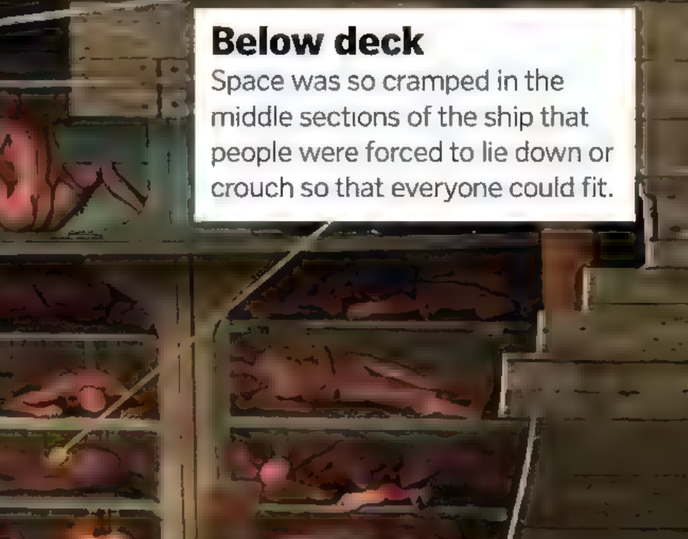
Bigger ships
In the early 18th century, slave ships were over 60 tonnes on average. Custom-built slave ships increased to 180 tonnes by the end of the century.

The anti-slavery movement

Throughout Britain's involvement in the slave trade, there were always those who acknowledged the injustice that came with forcefully transporting, owning and selling other human beings. As slavery became more prevalent, more people let their disapproval be known.

Two of the most influential abolitionists were Thomas Clarkson and William Wilberforce. People had heard some stories of the conditions faced by slaves, but Clarkson spent time creating an in-depth study of the trade. Publishing his findings on how slaves were being treated worse than animals, he spread this vital knowledge. Travelling across Europe, he campaigned against these wrongdoings, creating a mass movement by recruiting supporters.

William Wilberforce played his part from inside parliament. Inspired by the work of Clarkson, he spent 18 years introducing anti-slavery motions in parliament. After much persistence, and many persuasive speeches, his case was won and the law was changed.



Thomas Clarkson often spoke at the Anti-Slavery Society as a lead campaigner

1772
It is ruled that slaves brought to England can't be forcibly removed and returned to where they were taken from.

1782
Letters written by Ignatius Sancho, who was enslaved as a young child, were published. This gave a first-hand account of the horrors he faced.

1791
Parliament rejects William Wilberforce's first bill to abolish the slave trade by 163 votes to 88.

1791
The Haitian Revolution was led by Toussaint L'Ouverture as slaves in St Domingue revolted. This involved burning plantations growing the sugar used for trades.

1804
St Domingue became the Republic of Haiti. This was the world's first black-led state to be declared outside of Africa.

1807
Parliament passed An Act for the Abolition of the Slave Trade, meaning is was illegal to buy slaves. The Slavery Abolition Law was made law in 1833.

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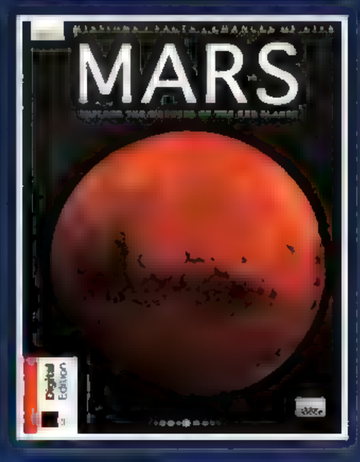

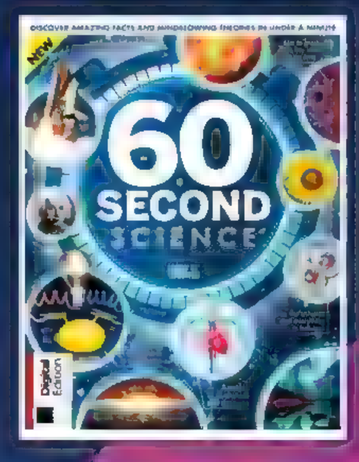

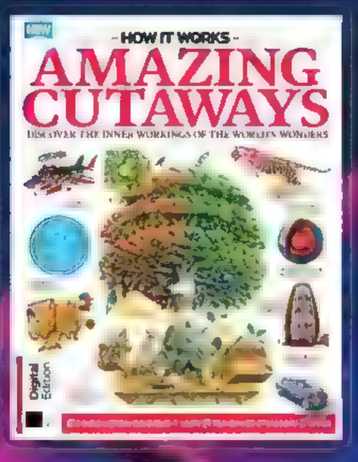

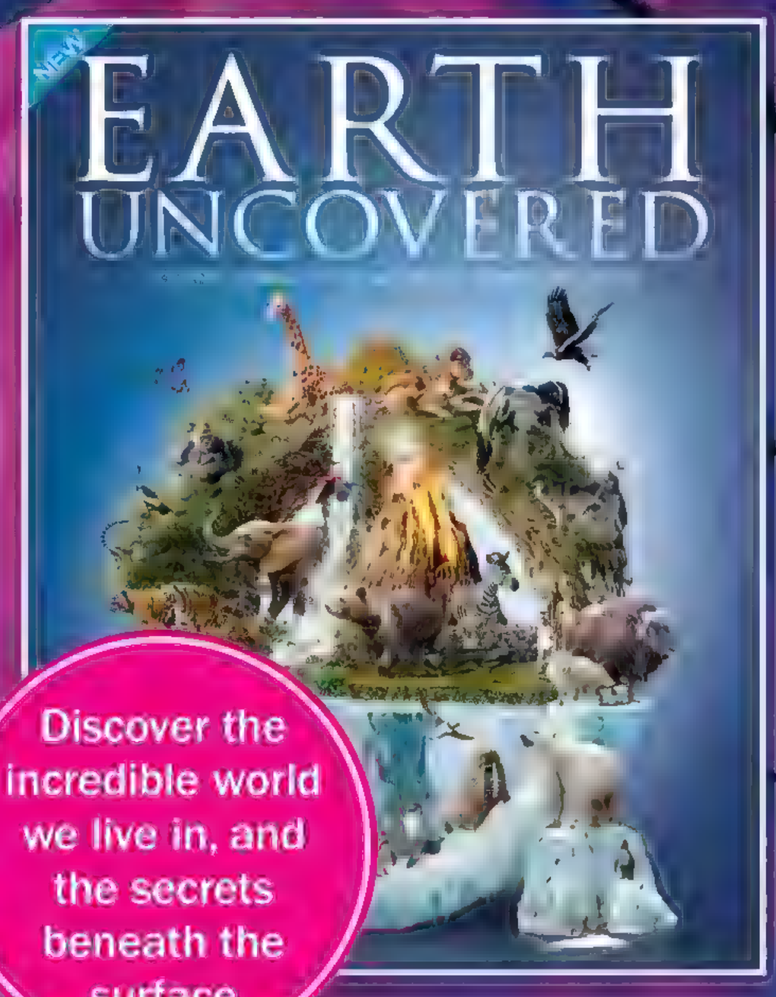

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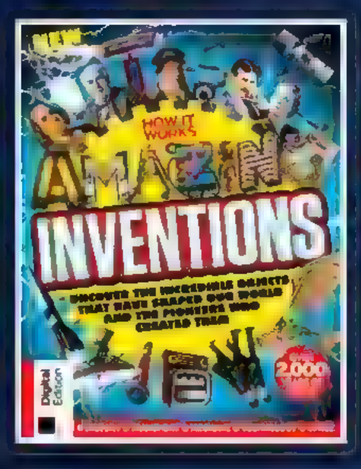

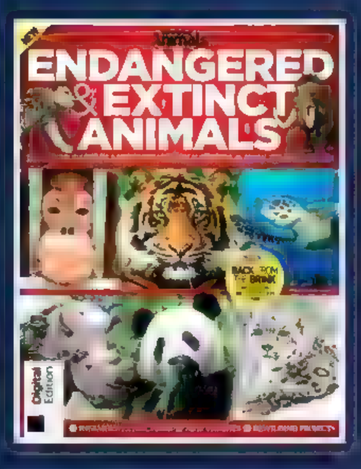

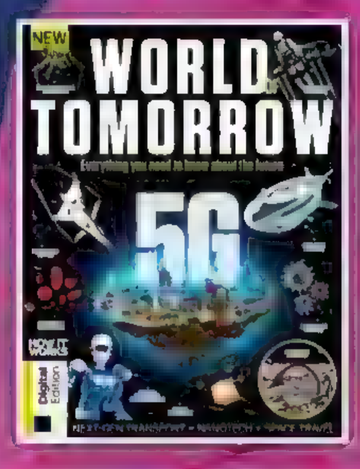

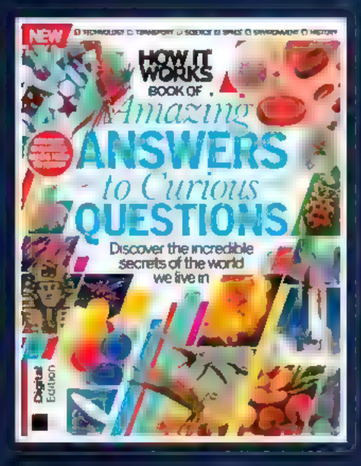

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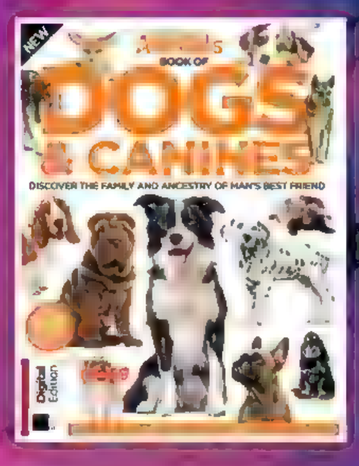

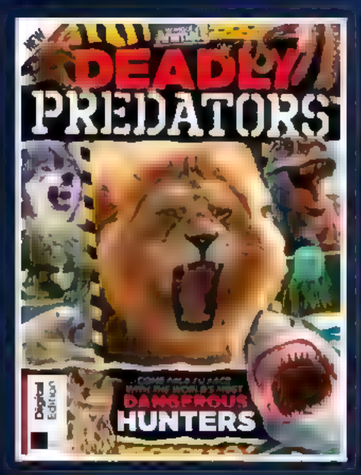

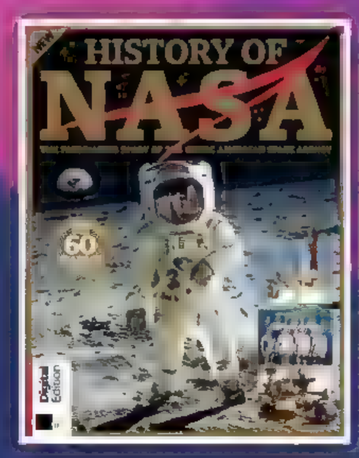

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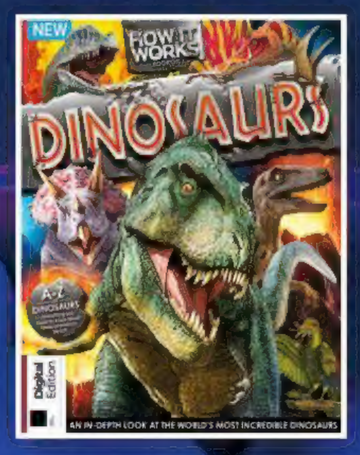

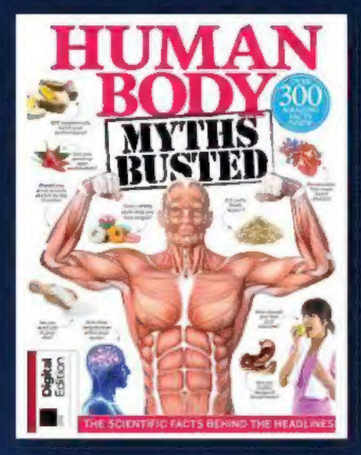

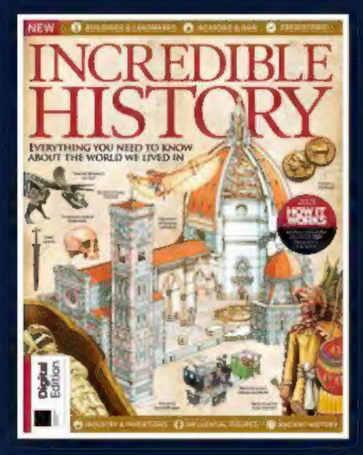

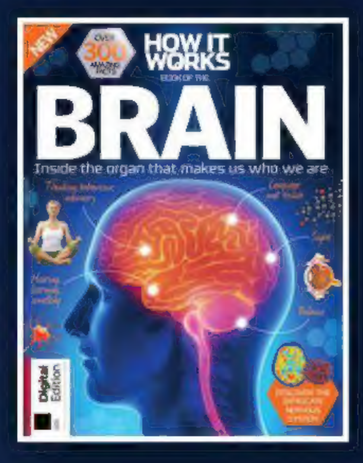

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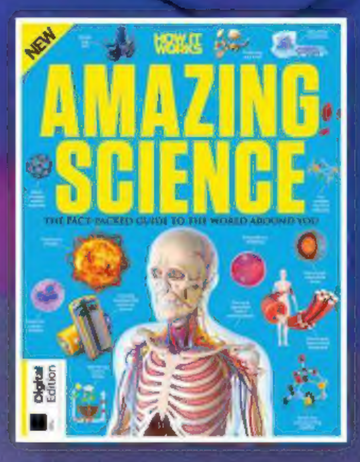

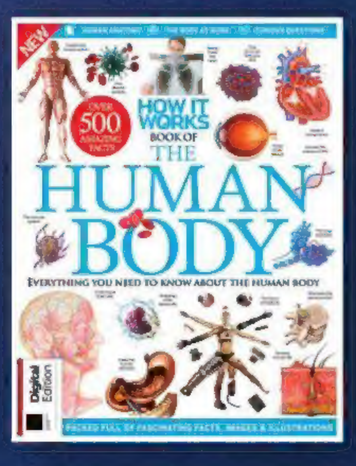

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